

THE MARCH SCIENTIFIC MONTHLY

EDITED BY J. McKEEN CATTELL

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THE SCIENTIFIC MONTHLY

MARCH, 1931

MATHEMATICS AND SPECULATION

By Professor E. T. BELL

CALIFORNIA INSTITUTE OF TECHNOLOGY, PASADENA, CALIFORNIA

THE rapid advancement of science is nowhere more strikingly apparent than in the numerous excellently contrived accounts of current science prepared for the scientific layman by professional scientists and by those who believe they understand what scientists are talking about in their ingenious theories. A reasonably critical mind, contemplating these brilliant expositions of fact or fascinating speculation on the apparent state, purpose and destiny of man and the universe, may become slightly confused by the subtly conflicting testimony of so many witnesses to the truth, but this is only a minor blemish on an otherwise encouraging picture of progress and universal enlightenment. The downright skeptic, looking for a light in his darkness, who closes more than one of these books or articles with the ejaculation, "God help the layman!" may be forgiven, for that help and no other is precisely what some authors abandon their readers with in their concluding chapters. And the reasonably critical mind will neither affirm nor deny, but continue to seek answers to such of its questions as seem to make sense.

Science has at last become articulate, not to say garrulous. Mathematics is not classed by some with the sciences, but this is of no importance here. What does matter is the fact that mathematics

can not descend to untechnical language so readily as the sciences. Non-Euclidean geometry, with all of its deep implications for metaphysics no less than for physics, began to pass into the common stock of knowledge only with the popularity of Einstein's general relativity, long after it had been a commonplace to the geometers. Modern algebra, even now, is only beginning to influence the speculations of physical science, and the theory of algebraic numbers and ideals, of no less philosophic interest than non-Euclidean geometry, is still all but unknown outside a narrow circle of arithmeticians.

Through its scientific applications, mathematics has been heard to a slight extent, it is true, but only indirectly. The significant contribution which mathematics might make to the present wide-spread appreciation of science has not been made. The confident user of "mathematics as a tool" is but seldom, if ever, troubled by doubts concerning the sharp implement in his hands, and few suspect that it can cut both ways. The more credulous seem to be unaware that mathematics is neither the handmaiden of science nor the servant of theology, but queen of the sciences, whose subjects must learn to distinguish between credible proof and plausibility, or perish.

Most reputable physicists, I presume,

would believe that they agree with Dirac that (his italics) "*the only object of theoretical physics is to calculate results that can be compared with experiment,*" even when some of them proceed to apply theoretical physics to speculations whose very nature precludes comparison with experiment. A similar remark applies to any science speculating outside its own specialty. The speculations as a rule are of but slight interest to specialists, and only the layman, who cares little for the dry technicalities of science, is taken in.

We are all laymen and largely ignoramuses outside our own narrow specialties. In particular, the mathematician looking at physics is merely a layman, and the theoretical physicist using mathematics is in general a mathematical layman. When a scientist wants anything at all from a mathematician it is usually help with some unimportant technical difficulty, like solving differential equations or evaluating definite integrals. Seldom if ever is a mathematician invited to examine the hypotheses which produced the equations or the integrals. If by chance he should catch a glimpse of the assumptions—often quite shocking to a cautious mind—beneath the mathematics and offer any remarks, he may be advised, in the words of a typical Cambridge tutor, to cut the cackle and come to the differential equations.

Now, the scientist's cackle is precisely what interests the mathematician as a scientific layman, for the differential equations are either too easy or completely beyond his powers—usually the latter if the scientist himself can't handle them. And the complete layman, who is neither mathematician nor scientist, cares nothing for differential equations, never having seen one in the flesh. Mach's "*Principles of Mechanics,*" with its few unobtrusive equations that can be skipped without losing a step, if one is reading chiefly for entertainment, is a

much chattier and humaner book than Lamb's "*Higher Mechanics,*" in which there is hardly an audible cackle from preface to finis. Which will the complete layman prefer? Each book fills its proper niche in a liberal education in mechanics. But a moderately clear understanding of one—I need not say which—is unlikely without a thorough mastery of the other or its equivalent. A less old-fashioned instance is offered by Eddington's two books on relativity, already classic so far as English-speaking peoples are concerned, "*Space, Time and Gravitation,*" and the "*Mathematical Theory of Relativity.*" Here, however, the division is less sharp, as certain passages in the two books seem to have skipped from one book to the other in their shuffle through space time.

Only when the mathematical layman and the scientific layman meet on the common grounds of speculation or hypothesis, does either believe in his heart that he can show the other anything with which he is not utterly incompetent to deal. On these debatable grounds the last word belongs as a rule to the most vociferous and the most credulous, and the interested bystander, who is neither a mathematician nor a scientist, goes away convinced that he has heard at least an echo of the eternal truth, whereas he has only been richly muddled by a loud noise. What the respective professionals suspect of being mere hypothesis, rank conjecture or baseless aspiration, although occasionally one is simple enough to deceive himself and gloss his suspicions for the benefit of the complete layman, passes for established fact in the uncritical mind which hungers to be convinced of something, no matter what.

I do not mean for a moment to imply that scientists are more addicted than mathematicians to speculation. Passage for passage, the wildest speculations of the scientists outside their own field can be matched by the like from mathema-

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ticians who have endeavored to tell mathematical laymen what mathematics is and what it is all about. Less than six months ago I came across, in a serious current mathematical publication, sponsored by a reputable mathematical association, this remarkable utterance, "Mathematics is the handmaiden of Theology." To some mathematicians at least such pronouncements are improper and distasteful.

The effect of speculations on those rather shy of the meager facts beneath the alluring speculations is illustrated by the eighteenth-century story of the mathematician Euler and the philosopher Diderot. Most mathematicians doubtless know it; but as some may be unfamiliar with De Morgan's corollary (which he added only to the second version in his "Budget of Paradoxes," 1872, p. 474), I give it in abridged form.

Diderot paid a visit to Russia at the invitation of Catherine the Second. At the time he was an atheist, or at least talked atheism: it would be easy to prove him either one thing or the other from his writings. . . . A plot was contrived. The scornor was informed that an eminent mathematician had an algebraic proof of the existence of God, which he would communicate to the whole Court, if agreeable. Diderot gladly consented. . . . (Euler) came to Diderot with the gravest air, and in a tone of perfect conviction said, "Monsieur! $(a + b^n)/n = x$; donc Dieu existe; répondez!" Diderot, to whom algebra was Hebrew . . . , was disconcerted; while peals of laughter sounded on all sides. Next day he asked permission to return to France, which was granted.

Now for De Morgan's corollary. "An algebraist would have turned the tables completely, by saying, 'Monsieur! vous savez bien que votre raisonnement demande le développement de x suivant les puissances entières de n .'" I imagine some mathematicians will sympathize with Diderot when confounded by new epistemologies, bizarre eschatologies and budding theologies hurled at their bare heads by the unscientific prophets of current scientific speculations. The worst

of it is that even the wildest speculations may be right for all that any helpless mathematician knows. Perhaps the best answer to the more bewildering conclusions of the prophets is to adopt De Morgan's suggestion, and demand that our tormentors express all their probabilities as cube roots of quaternions, in order to avoid the pitfalls of the excluded middle and so attain the necessary pitch of modern mathematical rigor.¹

2. The signal contribution which mathematics might make to the ever-widening dissemination of scientific ideas is a sharpening of the critical faculties and a deepening of intuitive insight. This could be accomplished, at least in part, by making accessible to those who are not professional mathematicians the profound disturbances of this generation and the one just past which have shaken to its very foundations the entire vast fabric of modern mathematics. The fundamental concepts involved, and

¹ By a singularly beautiful freak of irony this outrageous demand was not met, but was surpassed and then met a week after it was written. Proca (*Journal de Physique et le Radium*, (7), 1, No. 7, July, 1930, p. 247) interprets the ψ function in Dirac's equation as a quadri quaternion, whose 16 components are hypercomplex probabilities in his $(3+1+1)$ -dimensional space-time-matter world. These "quaternions of quaternions" (a Clifford linear associative algebra in 16 units with a modulus) are quantum probabilities. The author commends to mathematicians the problems thus created by his concept of *hypercomplex probabilities*. It is to be hoped that no mystic from his dimensionless world interprets this as a challenge from our $(3+1+1+1)$ -dimensional world of space-time-matter-sense; (as a world the new quantum probability universe seems to lack a dimension). For if, as some eminent scientists have recently informed laymen, the current non-imaginary probability interpretation of quantum mechanics reveals a Supreme Being, how many such Beings are revealed by quantum mechanics as a *sixteen-fold-imaginary system of probabilities*? Does not Proca's perfectly good and extremely interesting exercise in formal algebra reduce all such speculations to the level of Euler's refutation of Diderot, that is, to unseemly jests?

the language in which they are described, should present but few difficulties to a generation which has learned the patter of relativity and the metaphors of quantum mechanics. Indeed, in the whole discussion there is nothing so knotty as a curved space time, and little so slippery as the quantum hypothesis of uncertainty or indeterminacy, both of which are profoundly modifying thought outside their own scientific domains. The disputed points in the foundations of mathematics are in fact far simpler in appearance, and no less deceptively easy of apprehension, than most of the basic abstractions from which current physical speculation proceeds.

To this program one type of scientist will raise immediate objection. It is an old, old objection. Science is not mathematics. Most mathematicians are now aware of the fact. And they know also that mathematicians are often taxed with demanding proof in the strictest mathematical sense where it is absurd to demand such proof. They are also accused of haggling over straws when the haystack is on fire, and splitting hairs to splice a cable when the bridge is about to be washed out.

The classical instance is that of Laplace, who also had some claims in his day to be counted among the scientists. Napoleon Bonaparte, that eminently practical man, declared that this great mathematician failed as an administrator because he sought subtleties everywhere, and carried into politics the spirit of the infinitesimal calculus. This remarkable verdict was inspired in part by Napoleon's desire to oust Laplace in order to provide a profitable job for a nephew, who carried no sort of *esprit* into politics or anything else. Its injustice is evident from the most cursory inspection of Laplace's career. As a mathematician he did mathematics; as a politician he did politics, and did it in

a style suited to his patron and his times. The mathematician Cauchy also showed himself to be a practical politician of no mean proportions. And several mathematicians have been philosophers, or even scientists, of parts.

Whatever truth there may be in the general charge scarcely concerns us here, for the matters in dispute are simple, common to all consistent thinking and not obscured by any doubts as to the desired object. If it were ever true that to a pure mathematician all things are pure mathematics, it is no longer so. With the discovery of the past thirty years that mathematics is less pure than some mathematicians thought it, being contaminated by psychology, metaphysics and all sorts of other enticing impurities which some purists would like to boil off, the bigoted search for purity where it does not exist has ceased. It is precisely because many mathematicians have come to realize that nothing is so uncertain as seeming certainty, unless it be apparent uncertainty, that some of them hesitate to accept as worthy of serious human consideration the speculative conclusions of science outside of its own inhuman province.

On the debatable ground we are all laymen, pure and simple, and if the experience of mathematics means anything for science the conclusion of the whole matter is to be cautious—more cautious than any speculative presentation of current science would have us be. With the speculators in this connection may be classed those specialists who, in serious treatises, proceed to epistemological conclusions in apparent disregard of everything that has been done in the past thirty years in the foundations of logic and mathematics, and who seem to believe that every one understands what probability means when applied to the actual world.

3. When a scientist tries to jar a

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mathematician by boasting that he uses one theory on the even-numbered days of the week and an apparently contradictory one for the same phenomena on the odd days, he is disappointed when he fails. Frequently the scientist confesses a desire to reconcile his theories, and sometimes he succeeds brilliantly, as for instance with his waves and corpuscles. For twenty years or more mathematicians have been beating this poor showing of the scientists. It is a hopelessly antiquated mathematician who can not dispute the consistency of his fundamental assumptions while using the analysis deduced from them to establish theorems which one compartment of his mind believes to be true, while the adjacent compartment believes them to be not false but mystical nonsense. The last is merely the rather brutal characterization which some doubters, not content with half-way compromises, assign to ideal theorems in the technical sense of the thorough-going formalists.

Mathematical speculation, it would seem, can meet scientific speculation on terms a little better than equal. Unfortunately the two have not yet met in public, and scarcely at all in private. When they do meet, if ever, we may look for the most clarifying session in the history of human thought. And, if a prediction may be ventured, both participants in that shattering debate and all those fortunate enough to hear it will rise with considerably fewer convictions than encumbered them when they sat down. This, however, need not be taken seriously by any who cherish their present prejudices, for an example will be given later to illustrate the utter folly of most predictions concerning the futures of mathematics and logic.

Let us imagine for a moment that mathematical speculation and its younger scientific sister do meet to discuss their perplexities, and that they

retain sufficient poise to conceal their mutual disrespect. What, if anything, may either hope to learn from the other? From a dispassionate examination of her younger sister's effects, mathematics may conclude that unlimited publicity is not such a bad investment after all, and that a touch of humanity of the proper color now and then improves the general appearance and adds to the joy of living. The younger, impressed by the calm assurance of the other, after a life of disillusionments, may foresee her own future, and silently agree that no bread is better than half a loaf when the whole is moldy and ripe with weevils. In the meantime she will have her fling, and in the end attain the imperturbable serenity of her older sister, secure against all assaults of doubt, for she will have outgrown her adolescent ambition to rule society and the universe.

The above sketch may be unduly optimistic. There is little evidence to show that one clan can profit by the mistakes of its neighbors. Each goes its own way and learns, if at all, by experience. It may be useless to point out that mathematical speculation found it self-destructive to read into the conclusions of mathematics more than was given unequivocally by the strictest techniques of mathematics alone, subject to incessant examination and merciless criticism to detect concealed assumptions and flagrant contradictions. It may be a waste of time to recall that the simplest and most obvious of all the sciences has not yet agreed with itself as to what is provable, what not provable, what is sense, what nonsense, and what the provinces of meaning and inference are for the most rudimentary abstractions of which the reasoning mind has thus far shown itself capable. Unbridled speculation may not be checked by the history of any of the intellectual disasters to which it has led.

But surely the average intelligent human being will be moved to a little healthy hesitation in accepting the more preposterous inferences drawn by enthusiastic prophets of current scientific speculation when he suspects that even mathematics can not deduce sense from ill-understood concepts or from insufficient hypotheses. He may even begin to suspect that not every lame duck he sees is a swan.

Not even the most critical onlooker would presume to object to any purely scientific hypothesis or speculation which science may find convenient for scientific purposes. It is only when speculative solutions for age-old human or philosophical problems, which may not even have been properly put for all that any one knows, are confidently advanced in the name of science as worthy of human consideration that protest becomes relevant. Scientists themselves have objected in the past to unwarranted appropriations of their workaday stock in trade, and if they do not object now it may be because they have grown indifferent. Some who are merely scientific laymen feel, however, that the broadcasting of speculation has gone too far to be wisely ignored.

4. Anatomizing defunct speculations may not be a very clean pursuit, but it can occasionally indicate that some of the living are less healthy than they might be and show what is likely to kill them. Unless he were told the year in which the following alleged demonstration was put forth in a serious book which had a tremendous sale, an unsuspecting mathematician might well swallow it whole for a brilliant speculation fathered by current science. The occurrence of two ethers in the theory need not perturb a modern reader. Some physicists still find it convenient to speak in terms of an ether even when discussing relativity, and they do so with full knowledge and perfect pro-

priety. So let the innocent mathematician, who is only a layman in speculations outside his own, plunge into this with complete confidence that he is in reputable company.

Matter is made up of molecules (size A), which are vortex-rings composed of luminiferous ether. The luminiferous ether itself is made up of much smaller molecules (size B), which are vortex rings in a second or sub-ether. Call these smaller molecules and the sub-ether in which they are embedded the Unseen Universe. The human soul exists in the Unseen Universe. It is made of the smaller molecules (size B). In life it permeates the body like a subtle gas. The thoughts we think in life are accompanied by vibratory motions of the molecules (size A) of the brain. These motions undulate through the material universe. But, by the conservation of energy, part of these motions will be absorbed by the molecules (size B) of the soul. Therefore the soul has memory. On the dissolution of the body the soul with its memory intact becomes a free agent in the sub-ether. The physical possibility of the immortality of the soul is thus demonstrated.

It sounds like sense, but is it?

"The Unseen Universe" was not written by Euler in the eighteenth century. Nor was it intended as a satire for mathematicians and other scientific laymen. If I have done an injustice in the above rough, secondhand paraphrase—it is not too rough—to the distinguished scientists who made the "Unseen Universe" a best seller, I apologize to their sub-molecular molecules wherever they may be in their sub-ethereal ether. Turning to the title page we see the names of the distinguished British physicists, Tait and Stewart (the book was first published anonymously). It seems incredible that the same Tait could have collaborated with Lord Kelvin in the great "Treatise on Natural Philosophy," but possibly the influence of Kelvin (who was a devout Christian and who hated unwarranted speculation as violently as he once hated quaternions) kept the sub-ether out of the treatise. And it is little short of a

miracle that some practical joker has not gone Euler one better by erasing the date, 1875, and offering the all but forgotten classic to some book of the month club. It sold by the ton lot once; why not again? So far as mathematicians and reasonable human beings were concerned, the "Unseen Universe" was smashed flat by the mathematician Clifford. His essay on the subject still makes amusing reading, particularly for his own shrewd speculation which foreshadowed an essential part of general relativity.

5. To some readers of Eddington's "Nature of the Physical World" (1928), one of the best things in it is a sentence on the last page. "The religious reader may well be content that I have not offered him a God revealed by the quantum theory, and therefore liable to be swept away in the next scientific revolution."² The irreligious reader may perhaps regret the omission. And the mere mathematician, always in his humble status of scientific layman, will accept without question the dictum that "In a world of aether and electrons we might perhaps encounter *nonsense*; we could not encounter *damned nonsense*."² For to at least some mathematicians certain extra-scientific speculations foisted onto the science of 1930 seem to come perilously near to the second kind of nonsense and to be no better than the "Unseen Universe" of 1875.

It is all to the greater glory of mathematics to admit that we are *not* living in a world of "aether and electrons," but rather in a gorgeous muddle of tensors, wave-equations, q-numbers, Hilbert space and Hermitian matrices. Mathematicians as professionals are familiar enough with these things to

regard them with indifference; what interests the mathematician as a scientific layman is the question of what all these notations mean in reference to the actual world.

The answer that they are meant to mean nothing has been given. If that is all there is to it, many of us will be content. But is it the whole story? I think not, and I base my opinion on certain of the questions which scientific speculation propounds and talks about in books which are unmistakably serious and which make very heavy reading. Incidentally, one of the amazing things which impresses seasoned mathematicians trying to follow afar the recent developments of theoretical physics is the facile skill with which young men scarcely out of their teens handle the tricks of the mathematical game like masters. It makes Abel and Galois more real to us, and we can believe that such men actually lived a century ago.

After following as best one can some of the more speculative parts of the new theories, one need not stretch the imagination to frame the sort of question the candidate for a lay degree in modern theories may be expected to answer in 1931 unless something pretty drastic happens to our understanding of the famous uncertainty principle between now and then. Here is a specimen, frankensteined from a vivisection of the sole survivors from the destruction of the "Unseen Universe."

From the spinning electron, Heisenberg's uncertainty principle and the most recent attempts with which you are familiar to quantize relativity and relativize quanta, deduce consciousness, the freedom of the will and the existence of nonsense and hence show that an introverted mysticism is not incompatible with the good life, however well defined and however badly lived.

To this inhuman question the humane examiner may add a footnote, recalling what the uncertainty principle is (or

² A. S. Eddington, "The Nature of the Physical World." By permission of The Macmillan Company, New York, publishers.

was in 1928). The following simple description for laymen is due to Professor Eddington.³

Suppose that (ideally) an electron is observed under a powerful microscope in order to determine its position with great accuracy. For it to be seen at all it must be illuminated and scatter light to reach the eye. The least it can scatter is one quantum. In scattering this it receives from the light a kick of unpredictable amount; we can only state the respective probabilities of kicks of different amounts. . . . if the kick is small the probable error will be small.

The short mathematical statement may be found in any one of numerous recent treatises. It need not concern us here. Like the foregoing, all involve the notion of probability or of a statistical measure in the mathematical senses as commonly applied by orthodox scientists. This point is the only one of interest to critical mathematicians.

Those who find difficulty in visualizing the probabilities of quantum mechanics may be helped by the ingenious interpretation of Schrodinger's psi function as an imaginary probability.⁴ It really is quite simple; starting from Borel's concept of probability as a certain real arithmetic in the interval 0 to 1, the mathematician may proceed to resolve any number in the interval into a pair of conjugate complex numbers. Schrodinger's psi multiplied by its conjugate is usually interpreted as a probability. Hence Schrodinger's wave equation describes the distribution in real space and time of imaginary probabilities. The possibilities thus introduced for hyperscientific epistemology are unlimited.

Now, no scientific layman has a right to object to any inductions from the uncertainty principle within its own domain. But what are mathematicians

and other mere laymen to think of the devastating generalizations inferred from the principle outside the region of physical science? For example, it is an interesting current speculation that strict causality is rendered meaningless and that all the philosophical implications of determinism are abolished by the principle. But are they? Doubtless many mathematicians as well as other laymen would be glad to see the last of all obscure speculations, materialistic or idealistic, deterministic or indeterministic. They may be disappointed if they expect the uncertainty principle to do their housecleaning. For it all depends upon the meaning of one word, probability. On this point there seems to be considerable haziness, which is perhaps even a more hopeless situation than a sharp division of opinion.

My own belief, for what it may be worth, is that these extra-scientific inferences from the principle can not tarry "to be swept away in the next scientific revolution." I believe that they have already been swept away, as mere straws on the general flood, in the present mathematical revolution, which has been in full tide for a generation and is still going strong. They have therefore already attained that unblest state which Eddington calls "damned nonsense." However, this is merely a personal opinion, liable to be swept away in the next mathematical revolution.

6. That equally competent experts should disagree on the meaning of probability seems a sufficient reason that the inexpert should suspend judgment on the wider speculations originating in the quantum uncertainty principle. There is of course no doubt as to the "meaning" of the formal definitions in the text-books on probability or least squares. For the most part they are so trivial that even beginners can apply

³ A. S. Eddington, "The Nature of the Physical World." By permission of The Macmillan Company, New York, publishers.

⁴ Proca, "Mathematica," 1, p. 22, 1929.

them with ease to problems on games of chance few of them have ever played.

What is in dispute is the step from the purely mathematical definitions to their applications to the actual world. If one set of opinions regarding the meaning of probability should turn out to be right, then all the wishful abolitions of superfluous philosophies will be justified. Should the same set of opinions turn out to be wrong or inadequate, the position will be one of stalemate, and for all of any one's desire to get rid of certain speculative systems of the past we shall still have them with us.

Probability and what comes out of it beget innumerable instances of the kind of mathematical precision which exasperates the confident user of "mathematics as a tool" into calling all mathematicians who are more than animated calculating machines vain quibblers. The dishonorable "mathematics is the handmaiden of science" tradition also shows up here in all its shabby splendor.

For example, any genial expert on thermodynamics will expound the meaning, not only of probability, but of its logarithm to any doubting or obtuse mathematician. The mysterious logarithm takes on the minatory semblance of a time arrow, and the mathematician hears the death rattle of the universe as it runs down like a rusty and worn-out alarm clock. The time arrow, carefully avoiding the circular points at infinity, is never perpendicular to itself; the entropy increases monotonously to its proper maximum, and the frozen mathematician awakes in a very cold sweat indeed, to find himself flat on his back on the void floor of absolute zero. Awakening from his nightmare he is informed that, if not damned, he is lucky to be alive in this brightest and best of all possible universes in this best of all possible times. Muttering that this singular conclusion is extremely improb-

able (its "probability" is the limit of one divided by a number that tends to infinity), the mathematician departs to think over exactly what it was that the scientist did to him. But he is alone and without solace, for the handmaiden fled to drown herself in the kitchen sink when her employer began the pragmatic part of his demonstration.

It ran as follows: "My hypothesis is true because it works. The hypothesis was P. Now P implies my proposition Q, as can be verified both mathematically and experimentally. But Q is known to be true. Therefore P is true. Now again, P implies R, as can be shown mathematically and verified experimentally. Therefore, since P is true, so also is R."

To which the bewildered mathematician might reply, "Why go to all that bother to 'prove' that R is true? Wouldn't it be simpler and much shorter to substitute a false proposition F for P at the beginning? Then you could get the whole alphabet at one clattering swoop instead of your single R, for a false proposition implies any proposition you like. It is no trick at all to square the circle by this method."

If this is a travesty of legitimate reasoning with probabilities in the strict and unromantic domain of statistical mechanics, what of the epistemological and humanistic parodies of the quantum uncertainty principle put forth by some of its more daring interpreters to impress imaginative laymen? Is either kind of travesty more far-fetched, nonsensical and absurd than the other? If you think so, consider Whitehead's query in a similar connection: "What is the sense of talking about a mechanical explanation when you do not know what you mean by mechanics?" Then, if you find sense where Whitehead seems to find none, and still think one travesty more sensible than another, you are the only layman living who will admit that

he understands the speculative, extra-physical applications of quantum mechanics to their last h.

7. Even a critical mathematician will grant that a theoretiker is within his rights when he imagines his swarms of particles distributed in any way he pleases in their neat pigeonholes in space of the proper number of dimensions. Mathematicians themselves have been doing similar tricks with variously colored balls and urns since the time of Fermat and Pascal. But it is only a very naïve and unsophisticated mathematician who believes that his amusing game has yet been proved to mean anything essentially more profound than juggling with the proper fractions deposited by a suspiciously prolific definition. A cautious juggler would hesitate long before admitting that he knew—if he thought he did—what is meant by the phrases “random distribution,” “random sample” and “equally likely.” Without a clear understanding of what these elementary things mean in relation to inferences concerning the actual world, it is difficult to see how inductions from statistical theories can make any significant contribution to epistemology, or even to theoretical physics as distinguished from mere algebra and arithmetic.

The newer theories have gone far beyond the elementary notions of mathematical probability. The very questions which it would be of supreme interest to answer appear to be presupposed in a hopeless tangle of inexplicit postulates, ambiguities where precision is essential, and elementary mathematical processes of the game of probability; and the final outcome beyond the algebra and arithmetic appears as a vicious circularity so far as epistemology is concerned.

To all this the confident scientific user of probability replies that the pragmatic test suffices; the theory

works. It predicts quantitative results that can be checked by experiment. This merely emphasizes the question. Why does the theory work? And why has the Gaussian or any other statistical law of error anything at all to do with the actual world? Some scientists would say that the questions are meaningless; others are bolder, and point to their epistemological conclusions as the answer, believing that they have not begged the question. Does not this suggest that such speculations are beyond the present range of science and not to its credit? In any event it is pretty certain that the pragmatic answer is not that which the layman, interested in such things, believes he is getting when presented with one in the name of science. And the step from purely scientific or mathematical applications of the ill-understood concepts of probability to the profound and possibly meaningless riddles that have plagued human thought for centuries is so vast that more than the seven-leagued boots of science are called for to take it.

Any attempt at the present time to stride over the real difficulties of probability to easy and impressive conquests outside its scientific territory are to some minds as repugnant and as improper a use of scientific method as was ever imagined. To such minds the epistemological and other extra-scientific speculations, originating in the quantum uncertainty principle, are on a par with Pascal's wager. If any modern interpreter of science to the layman has forgotten that infamous misuse of purely mathematical reasoning by one of the founders of the theory of probability, let us briefly recall it.

“As the value (say v) of eternal happiness must be infinite,” according to Pascal, “then, even if the probability (say p) of ensuring eternal happiness by a religious life be very small, the expectation (which is p times v , and is the

usual basis for computing the price of lottery tickets) must still be great enough to make it worth while to be religious."

For nearly 300 years Pascal's bet against the devil has stood as the unchallenged record of bad taste in speculation. It also is a fair sample of the ridiculous authority which mathematics was once wont to claim in regions where it knew nothing. Reputable mathematicians outgrew this sort of thing long ago. The scientific speculations of the popularizers still seem to be tempted by the abomination.

All these doubts concerning the significance (if any) of probability as applied to the actual world may be removed tomorrow. The meaning of probability as something more than a byplay of the intricate mathematical game may be cleared up overnight. Even now some mathematicians would say that there are no doubts. To them the whole situation is clear, including the long controverted status of inverse probabilities.

Some of us will recall the amused contempt with which the investigations of Keynes, in 1921, on probability were received by some hard-headed professional mathematicians, expert in the theories of probability and statistics. Those investigations were a serious attempt to state some of the real difficulties competently and to break away from the algebraic trivialities which are sometimes mistaken for the theory of probability. That the effort was in part abortive was only to be expected from the nature of the problem, and the more recent work of Nicod bears out the critics to a certain extent, but not for the reasons they assigned.

It can not be too strongly emphasized that these subtle questions considered by the logicians of mathematics are precisely those which must be settled before epistemological or hazier speculations

founded on probability as used in physics are more than a waste of time. The mere arithmetic and algebra of the situation are not in dispute and never have been since the infancy of the theory. Some mathematicians dismiss the difficulties with the epithet "metaphysics." These overlook the disconcerting fact that much of classical analysis has been forced into intimacy with what many orthodox mathematicians only thirty years ago would have branded as metaphysics, and pretty wild metaphysics at that. Kelvin's compliment that "Mathematics is the only good metaphysics" seems to be coming true, but turned inside out, as it were, with a strong reverse English.

Other experts, equally competent, profess to see difficulties in the very beginnings of the theory of probability as great as those surrounding the notorious axiom of choice. Problems in the foundations of mathematics, no more difficult in appearance than those connected with probability, have defied precise formulation, to say nothing of solution, for more than a generation, in spite of all the efforts of some of the ablest mathematicians and subtlest logicians the world has ever known, to compass them. What is the human value of speculations founded on quicksand?

Probability, as Russell recently remarked (I quote from memory) is the most important notion before the scientific public to-day. Laplace in his day said the same. And nobody, Russell added, has the slightest idea what it means.

Many mathematicians will agree with that verdict. Many scientists, as I know at first hand, will see in it only the critical mathematician's alleged propensity to quibble over the obvious judgments of common sense. The layman who looks at mathematics from the outside is free to take his choice. If he

is gifted with uncommon sense, he may suspect that common sense is not the ultimate tribunal before which such questions must be tried. In the meantime he may accept a Scotch verdict of "not proven," and speculate to his soul's content and the creeping paralysis of his critical faculties, for no one on earth can *prove* that he is wrong.

8. A common and engaging trait of the truly eminent scientist is his frequent confession of how little he knows. A critical mathematician trying humbly to understand the works of some of the greatest scientists is sometimes moved to an opposite estimate. They know altogether too much.

Instead of the copybook aphorism often ascribed to Laplace as his last utterance, "*Ce que nous connaissons est peu de chose; ce que nous ignorons est immense,*" what he really did say is nearer the mark as some critical mathematicians think they see it, "*L'homme ne poursuit que des chimères.*" It is almost as if the great scientist-mathematician had carefully rehearsed the first with the scientific part of his personality, only to be tricked by the irrepressible mathematician in him blurting out the truth at the most awkward moment of his life. He never spoke again.

If the scientist is modest, at least one school of mathematicians does not lack self-confidence. "In mathematics there is no *ignoramus*," according to the leader of the formalists. From its context this seems to mean that all mathematical problems can be unambiguously stated and that solutions exist, but as I am not sure of the meaning I shall not press this interpretation. Possibly it conceals a definition of mathematics: "That of which we can assert that we shall not always be in the dark as to its meaning is mathematics." Having heard itself described as anything from art to symbolic logic, mathematics can

survive any finite number of definitions.

Whether the problems of mathematics have been well posed, and if so whether solutions exist in any sense on which mathematicians can agree, seem to be questions for the future to decide or ignore. Experience has taught most mathematicians that much that looks solid and satisfactory to one mathematical generation stands a fair chance of dissolving into cobwebs under the steadier scrutiny of the next.

This is a different thing from the honest humility of the scientist, who foresees a possible end of his purely scientific speculations in the beginnings of others equally transitory. The bedrock beneath his dreams, the average scientist seems to believe, will stand unshaken under the hurricanes that blow away his airy palaces. What is incredible to a thoroughly critical mind viewing the wreckage of successive mathematical systems is that any one should yet believe in the existence of the bedrock.

Critical mathematicians have delved so deeply into the foundations of their rudimentary science without yet striking anything that any significant fraction of them all agree is bedrock, that they may be excused for disbelieving that others with clumsier shovels and blunter drills have got much below the deceptive surface of appearances. Like the most sanguine scientist, many a mathematician believes implicitly that the bedrock is there if only he could get through the quicksands, but the belief is not shared by all. The very existence of a reasonable doubt would seem to be a sufficient reason for boasting, not that we know so little, but that we know nothing.

In contrast to the modest assurance of the scientist, I believe (in spite of the formalists who, according to some critical logicians, have misunderstood the

nature of the issue) that it is not too strong to say that, on the things which really matter to them, mathematicians are reduced to taking their choice from among the members of that hoary and unholy trinity, ignorance, dogmatism and crass belief. Knowledge in any sense of a reasonably common agreement on the fundamentals of mathematics seems to be non-existent. Or, to put it another way, knowledge has become a function of belief; the more a mathematician believes (without proof) the more he thinks he knows.

It would be possible to arrange the eminent mathematicians of the present time into a sort of spectrum. The infra-red had better be left undescribed. The red end is complete skepticism toward the validity of mathematical reasoning. It shades gradually to a cool and comfortable green of utter indifference to everything but the merry antics of the problem-solvers, deepening into the beautiful blue of those who suspect that all is not as it should be with the green, but who believe that in the end they, and even the infra-red, will be purified into an ethereal violet. The violet is Cantor's paradise, the only genuine mathematics since the Greeks, according to W. H. Young, from which, as Hilbert has roundly declared, no one shall ever chase any one else. Beyond the violet stretch the illimitable regions of the ultra-violet, comprising all those who believe that the red and the infra-red are the unnatural offspring of forbidden quantum states, and that any who merely believe in the existence of the obscene progeny should be skinned alive and boiled in aqua regia.

That the controversies between one end of the mathematical spectrum and the other are real enough is evident from the considerable heat experienced as one passes along it in the improper direction. If they have done nothing else, recent disputes have abolished the

stupid, stuffed-shirt tradition that mathematics stands coldly aloof from all human animosities. This is a healthy symptom, for it shows that neither mathematics nor the average eminent mathematician is yet perfect, and therefore that both are still alive.

Some such arrangement of mathematicians of the past half-century, with quotations from their works, should do more to destroy a degrading taste for obscure and profitless speculation than a whole library of second-hand opinions. I believe it should be made, with a minimum of critical apparatus to clarify the technical terms, and distributed at cost to all those who care to keep a balanced mind. There should be no injection of personal opinion on the part of the compiler as to who is wrong and who is right. The bald exhibition of the facts should suffice to establish the one point of human significance, namely, that equally competent experts have disagreed and do now disagree on the simplest aspects of any reasoning which makes the slightest claim, implicit or explicit, to universality, generality, or cogency. There is but little question here of wide philosophical horizons. Many of the doubts concern such elementary things as the meaning of twice two equals four.

The last will doubtless raise a smile on the face of more than one scientist—should any happen to see it. Before passing to a few extremely simple examples to illustrate our changed outlook on the scope and validity of mathematical reasoning, I should like to state why I believe that some scientists are superior to some mathematicians in their ability to see two facts where none has yet been proved to exist. I recently heard Bertrand Russell somewhat rashly confide to an audience of scientists that he felt less confident than they of some things because he had tried for ten years, and failed, to prove

that twice two is four. This was perhaps only a picturesque way of stating that the all-essential proof of the consistency of mathematics is not forthcoming from "Principia Mathematica"—the defect which Hilbert and the formalist school are endeavoring to supply with their theory of demonstration, if the intuitionists will let them. Anyway, Russell's confession was received with a roar of laughter, and after the lecture several expressed the opinion that Russell's is the example *par excellence* of a brilliant mind seduced by its own subtlety. It will take a sharper implement than Occam's razor to shave these hairy logicians.

9. All shades of skepticism and belief as to the existence and quality of mathematical truth are to be found in the current literature of or about mathematics. At one extreme is the view of one school of psychologists that the profoundest truths of mathematics are nothing more than complicated motions of the human larynx, akin to the reflex swallowing of superfluous saliva. Midway is the innocent assertion of some mathematicians that mathematics is art. To me this is particularly exasperating, as I once spent a vacation near Carmel. If nothing else, in view of the controversies between intuitionists and formalists, the art theory of mathematics is so devilishly like the apparent truth as to be unkind. At the other extreme is the speculation that mathematics is true because of Platonic idealism.

The last in one form or another has been orthodox mathematical dogma for centuries, and it still claims its eminent devotees by the dozen. Many of course find it as repugnant as the saliva theory of mathematical truth. Unfortunately, the only middle ground possible seems to be the singularly barren and uninviting desert where mathematics as such is

divorced from its meaning, if it has any, and all of the interesting questions which a mere human being would like to ask *about* mathematics or its meaning are pitched into the limbo of meta-mathematics, a region at present as nebulous as Tartarus. Who but a confirmed juggler with symbols really cares anything about the hen track theory which reduces all mathematics to meaningless marks on dust or paper?

The answer of course is that some of the most eminent mathematicians living do take precisely that view and, quite disconcertingly, do seem to care for it tremendously. Some of us would scarcely blame the mathematical layman for feeling unsympathetic to this particular conclusion of one school of experts, but no one apparently has yet succeeded in demolishing the theory or demonstrating its irrelevance. If one takes refuge with the intuitionists, he is likely to be baffled by his inability to understand what they are talking about. At least some competent mathematicians have so expressed themselves. Here again the verdict is "not proven."

What was called above the Platonic view of mathematics (merely for brevity; there may be no foundation for it in Plato's philosophy) is seen in one of its extreme modern forms in the following quotation from a mathematical layman (Everett, 1870):

In the pure mathematics we contemplate absolute truths, which existed in the divine mind before the morning stars sang together, and which will continue to exist there when the last of their radiant host shall have fallen from heaven. They existed not merely in metaphysical possibility, but in the actual contemplation of the supreme reason.

According to this theory, mathematicians do not *invent* mathematical theorems; they *discover* them.

One of the great surprises of my life was to find that two of the most eminent

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mathematicians of this or of any age believe the Platonic theory in its uncompromising entirety. After such a shock as that I was ready to believe that all the undevout astronomers I know are madder than Nebuchadnezzar ever was. It is only fair to add the conclusion of the episode for the comfort of those who can not believe the Platonic theory. In a debate between the two mathematicians in question, in which the topic of discussion was the Platonic theory, the argument came to a sudden and disastrous end when each, as if at a preconcerted signal, hurled at the other the epithet "theologian!"

An interesting side-light on the respective leanings of those who believe the Platonic theory and of others to whom it is meaningless, appeared in a recent examination (with which I had nothing to do) given to about 300 students of science, mathematics and engineering. They were asked, "Were the theorems of elementary geometry which you studied in high school invented or were they discovered?" To a man the future scientists and engineers answered "invented." The intending mathematicians unanimously voted "discovered." Perhaps the correct answer is that silly questions are unanswerable.

A more modern variant (1928) of the theory emerges from the writings of one of the many working mathematicians to whom formalism does not seem to promise an escape from our serious mathematical difficulties.

It concerns the as yet (1930) unproved conjecture of the eighteenth-century mathematician Goldbach that every even number is the sum of two primes; thus, $8 = 3 + 5$, $24 = 11 + 13$, etc. More broadly, the doubt is about "real" propositions.

I (Hardy) ask them, finally, whether there is anything in the proposition, as relevant to logic and as Wittgenstein seems to conceive it,

which affords any justification for my belief in 'real' propositions, my invincible feeling that, if Littlewood and I both believe Goldbach's theorem, then there is something, and that the same something, in which we both believe, and that that same something will remain the same something when each of us is dead and when succeeding generations of more skilful mathematicians have proved our belief to be right or wrong. I hoped to find support for such a view when I read . . . when I read further, both in the book itself (Wittgenstein's "Tractatus Logico-Philosophicus") and in what Russell says about it, I concluded I had been deceived. . . . So here I can find no support for my belief, and if not here where am I likely to find it? Yet my last remark must be that I am still convinced that it is true.

That is also the conviction of many working mathematicians. Anyhow, whether they believe in the theory of mathematical truth to which their belief in a particular "ideal theorem" commits them, or whether they boldly ignore any doubts which may ultimately nullify their conclusions, they keep on working. If the theory itself has not yet been made to work, it has the undeniable merit of making scores of productive mathematicians work who might otherwise give up in despair. Skepticism, however, is not necessarily a damper on creative work, whatever those who dislike it may imagine; witness Kronecker.

A yet simpler illustration from the same source is this: "If I can not admit that 'there are infinitely many primes' has no meaning, it is simply because it seems evident to me what the meaning is." Less than thirty years ago few rational human beings would have doubted that the assertion about primes has a clear, simple meaning. To-day, it is classed by some with apparently meaningless noises, like "2 implies that 2 implies 2," which is an example of what some call "ideal theorems."

When I remarked earlier that the philosophical implications of the theory of algebraic numbers had escaped gen-

eral notice (perhaps fortunately) I had ideal theorems in mind. Any one reading Hilbert's paper of 1925 (*Mathematische Annalen*, vol. 95), and his earlier works on the postulational method in mathematics, will be interested in tracing the evolution, unconscious perhaps, of his thought through the great report (1894) on the theory of algebraic numbers and ideals to the epoch-making treatise on the foundations of geometry (1899), down to the present theory of proof, whose aim is to establish the consistency of mathematics as mathematicians know the subject and as scientists blindly use it.

And, while one is speculating, he may try to imagine what Hilbert's theory would have been like had the report on algebraic numbers never been written. The analogies from ideals might have been replaced by more familiar ones, such as the use of ordinary complex numbers in the proof of real identities. But, at that, one imagines, the shades of Cauchy and Kronecker, the one with his algebraic keys, the other with his more easily apprehended modular systems, would rise to object and claim a hearing for their less mystical constructions. Ideal theorems, one imagines, would have a hard time evading the test of constructibility which Kronecker imposed upon his mathematical creations. They can of course escape any such cramping prison by soaring to a higher type of mathematical truth. But if they take that way out of the world of sense they will need an ideal axiom of ideal reducibility to bring them back again, and such axioms seem to be under suspicion at present.

A strict finitist might dismiss all ideal theorems as being beyond the province of mathematics. But, in dismissing them, he would say goodbye forever to a great host of mathematicians whose works many still find interesting and profitable.

Entirely elementary difficulties like those quoted bring out more sharply than others, perhaps greater and closer to the professional activities of mathematicians during the past seventy years, the quandry in which mathematics today finds itself. For this reason I have avoided allusions to current controversies about the infinite, the theory of assemblages, the use in modern mathematics of Aristotle's law of the excluded middle and the method of indirect proof, and existence theorems, all of which are being attacked with varying degrees of ferocity by those who call themselves finitists and intuitionists.

I have tried merely to suggest to mathematical laymen that the present state and past experience of mathematics would seem to counsel extreme caution in accepting any speculation begotten by science on too willing mothers outside its traditional province.

The incredible but true and rather humiliating aspect of the present disputes over the validity of mathematical reasoning is not that we are offered a choice between cold skepticism and emotional belief, but that such a choice respecting sober propositions of everyday classical mathematics, such as the scientist uses constantly and without question in his work, is not itself flagrant nonsense. The sane, middle road which some would wish to travel has not yet been proven to exist, and those who try to take it in the prevailing darkness may find themselves falling down an abyss.

10. After all this, is there any good reason why mathematicians should feel discouraged? I believe not, and I shall try to justify my belief by two howlers which I came across recently. There are many more like these if any curiosity seeker cares to hunt for them. Here is the first, and it beats anything that any pessimist can possibly imagine.

"The golden age of mathematical literature is undoubtedly past."

This is significant only when it is dated. The year is 1813, and the prophet was the English mathematician Charles Babbage, of calculating engine fame, writing in the preface to the "Memoirs of the Analytical Society."⁵

In 1813, Riemann was -13 years of age, Hermite -9, Cayley -8, Kummer -3, Sylvester 1, Galois 2, Weierstrass 2, Jacobi 9, Abel 11, Lobachevsky 20, while Cauchy was living on borrowed time at the ripe age of 24, and the venerable Gauss was still lingering on in his dotage at the extreme old age of 36. These dismal perspectives might be continued far, but for the repose of Mr. Babbage's soul we forbear.

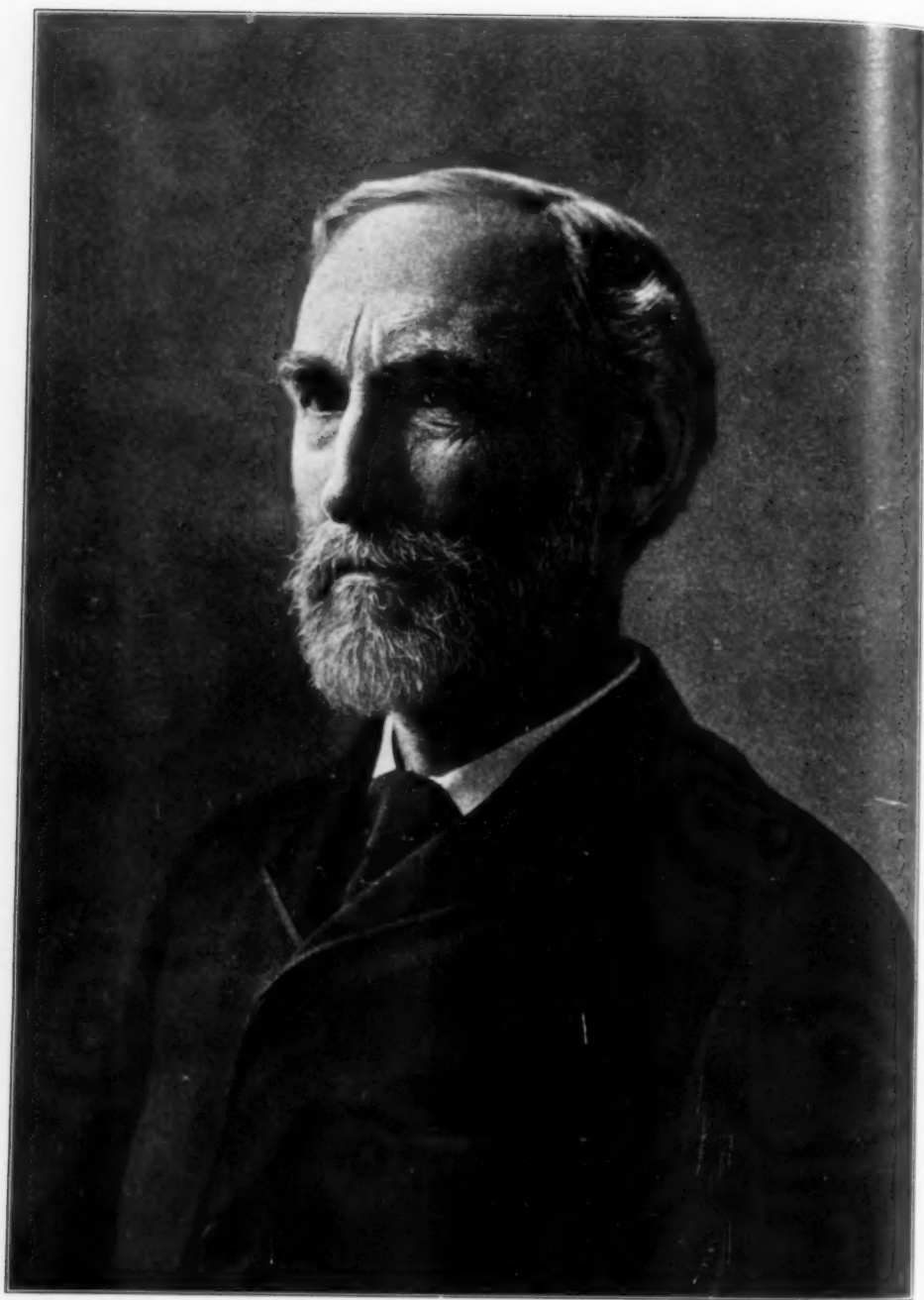
When Babbage wrote, there was but little in the luxuriant literature of mathematical analysis that a student of Abel, Cauchy and Weierstrass would

⁵ The preface and the memoirs are unsigned. For the information that the preface is due to Babbage, I am indebted to Professor R. C. Archibald. A copy in the Brown University Library has the names of the authors written in.

recognize as proof. By the time the intuitionists, finitists, formalists and others have settled their differences or agreed to differ *ad infinitum*, there may be as little left (according to the pessimists) in the rigor of Abel, Cauchy and Weierstrass for our successors to admire as that great triumvirate left intact from their predecessors for us to believe. But hear Mr. Babbage on this point, again speaking in 1813.

The foundations of a vast edifice (mathematics) have been laid; some of its apartments have been finished; others yet remain incomplete; but the strength and solidity of the basis will justify the expectation of large additions to the superstructure.

As Babbage can not be held responsible for not having heard of Kronecker, Brouwer, Weyl and Hilbert, we may overlook his unfortunate slip about the basis, and, on the intuitionist principle that two wrongs are as likely as not to cancel and leave one right, predict that 1930 in retrospect will appear as a worse year for prophecy than even 1813.



J. William Gibbs

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REMINISCENCES OF GIBBS BY A STUDENT AND COLLEAGUE

By Professor EDWIN BIDWELL WILSON

SCHOOL OF PUBLIC HEALTH, HARVARD UNIVERSITY

WHEN last spring I was asked to agree to give the Gibbs' Lecture on this occasion, I assented on the assumption that before the time came for the lecture to be delivered I should have been entirely relieved of my executive responsibilities to the Social Science Research Council and should have had opportunity to prepare from a considerable dossier of investigations in progress a scientific paper somewhat fit to take its place with the previous lectures given in this series.¹ As it has turned out, I have not had in full the expected relief and must appear before you with a very general talk of a personal and reminiscent nature. I will not apologize; it may well be that you prefer that type of address from me, and in view of its type I must be expected to speak without apology a good deal in the first person. After all, one's personal recollections are his own; they may have little of truth in them, for memory is not infallible; to use a detached third-person style of composition may give them in appearance a greater substance of objective fact than they really merit.

To give you some appreciation of the very inadequate background with which

I at the early age of twenty came into contact with J. Willard Gibbs may I state that my undergraduate work was at Harvard and in mathematics, which meant pure mathematics. In the spring of 1899 Professor W. F. Osgood, with whom I had taken a number of courses and who was good enough to take a real and much appreciated interest in me, suggested that I go to Yale for my graduate work. Some of you who have a knowledge of the relative standing in pure mathematics of the departments at Harvard and Yale at that time may think the advice extraordinary. It was, but it was extraordinarily good. As Professor Osgood pointed out, I had been long enough at Harvard and had specialized sufficiently in mathematics to get the greater part of the best Harvard had to offer in point of view, and a change would be beneficial to me.² He spoke of Pierpont and of Percy Smith whose interests were somewhat different from his own and those of Professor Bôcher with whom I had had more work than with any other than Osgood. It is my impression that neither Osgood nor Bôcher mentioned Gibbs to me. But when B. O. Peirce heard that I had decided to go to Yale he remarked that down there I might come across Gibbs "whom some of us here think a rather able fellow." Had

¹ M. I. Pupin, "Coordination," 1923; Robert Henderson, "Life Insurance as a Social Service and as a Mathematical Problem," 1924. Bull. Amer. Math. Soc., 31, 227-252, 1925; James Pierpont, "Some Modern Views of Space," 1925; *Ibid.*, 32, 225-258, 1926; H. B. Williams, "Mathematics and the Biological Sciences," 1926; *Ibid.*, 33, 273-293, 1927; E. W. Brown, "Resonance in the Solar System," 1927; *Ibid.*, 34, 265-289, 1928; G. A. Hardy, "An Introduction to the Theory of Numbers," 1928; *Ibid.*, 35, 778-818, 1929; Irving Fisher, "An Application of Mathematics to the Social Sciences," 1929; *Ibid.*, 36, 225-243, 1930.

² This sort of generosity is not unusual at Harvard; taken with reasonably good provision for traveling fellowships, it has deprived the Harvard Graduate School of a goodly number of students of the best grade, much to the advantage of the students and of science, and thus indirectly to the advantage of the university.



SAMUEL WILLARD

PASTOR OF OLD SOUTH CHURCH, BOSTON. GREAT, GREAT, GREAT GRANDFATHER OF GIBBS AND VICE-PRESIDENT OF HARVARD COLLEGE. (HE WAS PRESIDENT IN FACT BUT VICE-PRESIDENT IN NAME BECAUSE HE REFUSED TO LIVE IN CAMBRIDGE AS WAS REQUIRED BOTH THEN AND NOW OF THE PRESIDENT.)

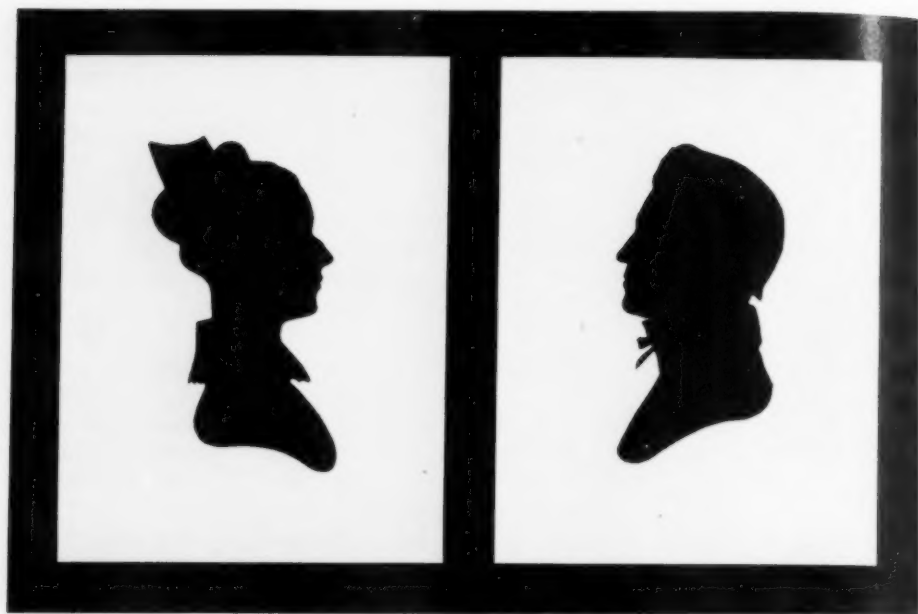
I know Peirce then as well as I came to know him later I should have taken this remark as indicating a person of the highest quality under whom I must surely plan to study, but at the time I disregarded it entirely. I went to Yale to study with Pierpont and Smith.

How came it that I studied with Gibbs? That was one of life's minor tragedies. When I got to Yale in the autumn of 1899 and was laying out my year's work with A. W. Phillips, dean of the graduate school, it appeared that there were only three courses I considered worth while, whereas four were needed for full-time work. Phillips suggested that I add Gibbs' vector analysis. I protested that according to its description it was not materially different from quaternions, of which I had had a full year under J. M. Peirce, and should hardly count as a course for me. The logic was unanswerable, but the circumstances overbore it; I had to have four courses and the dean would count vector analysis even though it was a sort of review; so I registered for it with a sneaking suspicion that my good master Osgood had made a mistake in sending me from a mathematically first-rate institution to a second-rate one. It was one of life's minor tragedies, but too late to be helped.

You are doubtless impatient that I should get along to talking about Gibbs and anxious for me to quit telling of myself; but I am just as anxious that you should realize what sort of person I was when I reached Yale after being graduated at the age of barely twenty at the head of my class with highest final honors in mathematics. I was certainly immature. I was not wise enough to be confident that a new place, new contacts, new points of view have sure advantages which overbear many a technical disadvantage. I was not wise enough to know that to take a subject twice from different angles and thus

better master the whole might be far better in the building of a scientific life than to be forever going on to some new subject, leaving everything both new and old with insufficient consolidation. It is not reasonable for you to suppose that, during the brief period from September, 1899, when I first saw Gibbs, to June, 1902, when I took leave of him to go study in Paris, never to see him again, I should have matured very greatly. If I could so have failed in seeing the significance of the remark of B. O. Peirce cited above, it is certain that I must have let slip many things of importance and misinterpreted or falsely remembered many others which occurred during the period of three academic years in which I came in contact with Gibbs. You and I alike are on very insecure ground in believing anything I may recount here to-day.

The course on vector analysis was small; none of Gibbs' courses had more than a mere handful of students, four or six or possibly eight. The course was difficult for everybody in it but me, and was easy for me only because I had previously had quaternions (which incidentally I had found difficult and perplexing, though I was amply prepared). The lectures followed the pamphlet which the author had printed privately in 1881-84 but had never published. There were no exercises assigned to the students to work—a truly continental type of course but embarrassing to Americans who are used even in graduate work to having the path made easy for them. The next year, thirty years ago this month, Professor Morris, editor of the Yale Bicentennial Series, asked me to prepare for that series a text on vector analysis and told me that Gibbs had given his consent and that I should talk the matter over with him. The conference was short. Gibbs remarked that he had prepared his pamphlet for the convenience of his students and for



SILHOUETTES OF THE MOTHER AND FATHER OF GIBBS

THE FATHER WAS PROFESSOR OF SACRED LITERATURE IN THE YALE DIVINITY SCHOOL, 1824-1861, AND SHOWED MANY OF THE INTELLECTUAL QUALITIES OF THE SON.

distribution privately. He said that he was busy preparing a volume for the same Bicentennial Series (his "Statistical Mechanics") and would not have time to advise on the composition of the "Vector Analysis," to read the manuscript or the proof, that I must be entirely responsible for the whole work, that I was free to write whatever kind of book I pleased, to incorporate so much of his course or pamphlet as I wished and to add whatever I desired from other sources. Somewhat seriously impressed with the magnitude and lonesomeness of the task I said I would do my best, to which he kindly replied that he had confidence that I would do very well, and after the book had appeared he was good enough to remark that it was satisfactory. That is about all the contact I had with him on the "Vector Analysis."

One topic which he treated at some length, but which I chose to leave out

of the book, was crystallography; another was the theory of orbits. The latter is adequately represented in his collected works, but the former is nowhere a matter of record and I am sorry that I omitted it, particularly as all my notes on all Gibbs' courses were lost overboard by careless handling on the part of the crew of the steamship on which I returned from Paris in 1903, so that I had thereafter no way of reconstructing from my notes special material from his courses not found in print. One of the ablest students Gibbs had had in the 'nineties was G. P. Starkweather, a person as systematic as he was able. He has written out with great care his notes on Gibbs' lectures. After his early death these notes were deposited in the Yale Library. It was chiefly from a volume of these that I was able to put together that part of Gibbs' course on multiple algebra which I found it desirable to print in

the *Transactions* of the Connecticut Academy in 1907 as a precursor to some uses I wished to make of the method in developing some geometrical theorems. I think it safe to say that the treatment of crystallography, though neat and interesting, was not of any great importance except as illustrating how the methods of vector analysis could be made to convert the goniometric measures taken on crystals into the desired constants of the crystal.

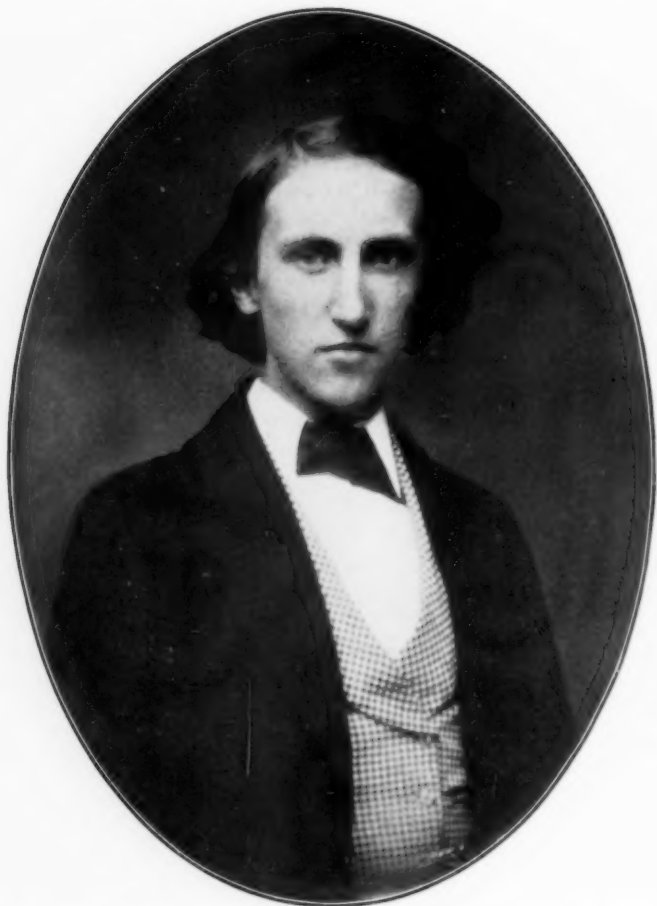
At one time when Pierpont was lecturing on elliptic functions with some reference to the motion of the top, Gibbs happened to be developing by vectorial methods and discussing the physical meaning of the equations of motion of the top. He turned to the class and with the pleasant smile which often lighted his countenance remarked that there were those who thought the top chiefly interesting as affording an exercise in the use of elliptic functions, but that he found the top a very interesting physical object on its own account. No criticism of another was implied in the remark, merely an emphasis on his own point of view which he was developing to his class. Although Gibbs had purely mathematical interests as in his

vice-presidential address on multiple algebra to the American Association for the Advancement of Science in 1886, and in his course on the same subject, his real abiding interests were in real physical things and he rarely if ever developed his mathematical theories of physics further than was necessary to get at the important physical significance of the phenomena he was discussing; his mathematical methods were the simplest which he could devise and often extended little beyond close logical analysis. That was one reason his courses were hard; technical dexterity is easier than thinking. Read the great thermodynamic memoir if you desire verification of these statements.

Except in the classroom I saw very little of Gibbs. He had a way, toward the end of the afternoon, of taking a stroll about the streets between his study in the old Sloane Laboratory and his home—a little exercise between work and dinner—and one might occasionally come across him at that time. Then there were the meetings of the mathematical and the physical clubs on occasional evenings with papers read by the staff or students. I do not remember that he ever read a paper on such



THE HOPKINS GRAMMAR SCHOOL
AS IT WAS WHEN GIBBS WAS A PUPIL, 1849-1854.



GIBBS AS A YOUNG MAN, FROM A DAGUERRETYPE

occasions, but he was usually in attendance and apparently paying close attention; sometimes he would make very brief remarks after the speaker concluded and the penetration of those comments was noteworthy. On one such occasion when we had been hearing of the then quite new electron theory of the constitution of the atom Gibbs said that it must be getting nearly time for him to move on, that for many years he had been troubled over the problem of reconciling the number of degrees of freedom in the molecules with the value of the ratio of the specific heats at constant pressure and constant volume and

that if we were to introduce all the new degrees of freedom implied by the electron constitution he would be still more at a loss. This was, of course, before the introduction of the quantum conditions.

He could be seen at faculty meetings, quiet and attentive. I do not recall hearing him speak but once, and then with few words much to the point. Once I ran across him in the library surrounded by books on the theory of numbers and reading a thesis on algebraic numbers just presented for the doctorate. I remarked that I had not realized that he was familiar with the



ANOTHER DAGUERRETYPE

theory of algebraic numbers. He replied that he was not, but that with the aid of some books he thought he might be able to come to a decision as to whether the thesis was worthy of acceptance. Once I desired to consult some books which were not in the library but which I had seen on the shelves in his office during a lecture. I ventured to ask whether I might borrow them. He was entirely willing. As I picked the books off the shelves I noticed that the pages had not been cut and inquired whether I might cut them, to which he replied: "Certainly, if you think it worth while." Probably I looked

abashed, for he added: "The author kindly sends me all he writes; there is a great deal of it; I sometimes feel that a person who writes so much must spread his message rather thin."

There may be some interest in a letter written by Gibbs to me just a month before he died:

New Haven Mch 28/03

Dear Mr Wilson

I think that you will have next year

2 hrs Non Euclidean Geometry

2 hrs Mechanics

2 hrs Introduction to Math.Phys.

6 hrs Freshman,

or something very like that. We will know better a little later.



HOPKINS GRAMMAR SCHOOL

AS IT WAS AT THE TIME GIBBS WAS A TRUSTEE, 1881-1903. GIBBS' INTEREST IN THE SCHOOL WAS ONE OF HIS VERY FEW INTERESTS OUTSIDE HIS WORK AND THE FAMILY CIRCLE. HE SERVED AS SECRETARY AND TREASURER OF THE BOARD FOR THE GREATER PART OF HIS PERIOD AS TRUSTEE AND SOMETIMES CONFERRED THE DIPLOMAS OF THE GRADUATING EXERCISES.

I think that the reasons wh you expressed so eloquently & I may add so discreetly to Dr. B—, would apply to an abridgement. We cannot take for granted that an abridgement wd not interfere with the sale of the larger book. The larger book is pretty heavily handicapped by its price, as it is. & in competition with a cheaper edition could hardly hold its own. Moreover, anything requires time to be well done, & I think to write a short book takes as much time as a longer one.

I did not mean to say that Hamilton did not have the equation

$$q^2 - 28q \cdot q + (Tq)^2 = 0$$

He doubtless would recognize the equation as correct, & may have written it in just that form. Only I do not see how he could have recognized that it is (I don't care whether you say, identical with or) analogous to the Ham. Cayley equation, because I suppose that he never was aware that a quaternion might be regarded as a matrix. I suppose that that was a discovery of the elder Peirce, as stated by Cayley in the chapter wh he wrote in Tait's "Quaternions."

I am glad that you find that instruction in America compares not too unfavorably with that in France. However, what you want to do is to get the best you can out of France, wh certainly will be a great addition to anything wh you may get here. I am a little surprised that you find the French Lecturers *going to pieces*. I had supposed that that was just what they never did—that they always gave their lectures in good form.

Yours truly

J. WILLARD GIBBS

Let me interrupt these personal reminiscences to give you a bit of history as it appears in the record. Gibbs was born on February 11, 1839. He prepared for college at the Hopkins Grammar School. He was graduated from Yale in the class of 1858 at the age of nineteen. In college his interests appear to have been Latin and mathematics, as he took prizes in each in more than one year of his course. He took the Bristed Scholarship of \$95 for the best examination in Greek, Latin and mathematics. He won the Latin Oration in both junior and senior years. He was awarded the Clark Scholarship of \$120 for the best examination in the studies of the college course which was conferred subject to the condition that the recipient continue as a graduate for one or two years pursuing non-professional studies. He did so continue and, in 1863, got his Ph.D. degree with a thesis: "On the Form of the Teeth of Wheels in Spur Gearing." In the Yale catalogues, of 1863-64 and 1864-65, he is listed as "Tutor in Latin"; in that of 1865-66 he appears as "Tutor in Natural Philosophy." Afterwards he went abroad to study. In the catalogue

of 1871-72 he reappears as "Professor of Mathematical Physics" and so continues until his death.

Except for his periods as tutor he taught only graduate work, although particularly competent undergraduates might be admitted to his courses, especially the vector analysis. It may interest you to follow the subjects he taught. From 1872 to 1881 the topics announced were capillarity, wave theory of light and sound, least squares, and potential theory with applications to electricity and magnetism. It is not to be presumed that he taught all these subjects in any one year, but the catalogues fail to state just which he did teach. It was in this period that the great papers on

thermodynamics were published, but there is no reference to his teaching the subject. In 1881-82 he added to his list a course on vector analysis, having apparently not given least squares for some years. The list continues with minor modifications through the catalogue of 1885-86. For the year 1886-87 we find the first pretentious catalogue, much larger than the preceding ones, with better descriptions of the offerings. The list for Gibbs is (1) vector analysis, (2) potential theory, (3) mathematical theory of electricity and magnetism, (4) electromagnetic theory of light, (5) the *a priori* deduction of thermodynamic principles from the theory of probabilities, and it so continues through the



THE OLD SLOANE PHYSICS LABORATORY

GIBBS' OFFICE WAS ON THE SECOND FLOOR AT THE RIGHT. THE LARGE LECTURE HALL BELOW WAS WHERE HE GAVE HIS LECTURES, EXCEPT WHEN HE GAVE THEM IN HIS OFFICE.



THE HOUSE AT 121 HIGH STREET BUILT BY GIBBS' FATHER WHERE GIBBS LIVED WITH HIS SISTER AND HER HUSBAND, ADDISON VAN NAME, LIBRARIAN AT YALE. GIBBS' ROOM WAS AT THE BACK OF THE HOUSE.

year 1891-92, except for the addition of a course on the computation of orbits.

It is of more than passing interest that the classical thermodynamics represented by his own contributions has not appeared for the fifteen years since his paper was printed and that the first course announced by him in this field is apparently really his "Statistical Mechanics" on which nothing was printed until 1901. In the years 1892-94 he apparently offered a combination of classical thermodynamics with statistical mechanics and only from 1894-95 on came to divide the work into a course on his great memoir with a supplementary one on statistical mechanics. In the meantime he had added an option in advanced vector analysis and another in multiple algebra. Thus after the middle

'nineties he may be considered to have run the cycle: (1) vector analysis, (2) advanced vector analysis, (3) multiple algebra, (4) thermodynamics and properties of matter, (5) statistical mechanics, (6) electromagnetic theory of light, (7) potential theory and theory of electricity. Of these (1), (4), and (6) were generally two hours per week throughout the year, while the others were one hour per week. He seems to have taught about six hours per week, giving (1) yearly with (4) or (6) in alternate years, and adding on occasion one or two of the other four one-hour courses. During the three years, 1899-1902, I was fortunate enough to take all these subjects, except that the statistical mechanics (5) was not given separately, but was represented as some ten lectures

at the conclusion of his thermodynamics 4.

Except for the vector analysis I, in common with all Gibbs' students of my time, was ill prepared for his work. It was not infrequently the case that a student repeated the work to become more familiar with it, and it certainly was my intention to repeat most of the courses after my return from Paris. The instruction was not poor, but the concentration of thinking of the instructor was great. Once in a while Gibbs would get lost in a demonstration. He lectured without notes and what specific preparation he generally made I do not know. It was almost always some very simple affair on which he would go astray rather than something recondite. The year I took thermodynamics he could not make his Carnot engine run right. There was a tradition, perhaps unwarranted, that the Carnot engine was apt to trouble him. Sometimes he would unravel his difficulty before the end of the hour and it was then an especial treat to see his mind work; sometimes the end of the hour would come sooner and he would have to leave the matter over until the next time when he would appear with a sheet of paper containing the demonstration.

I do not believe that Gibbs kept much in the way of notes. I imagine that he wrote the closely reasoned and highly mathematical "Statistical Mechanics" out of his head (rather than from notes accumulated during previous years) between the time in the autumn of 1900 when he agreed to produce the book and the time in the summer of 1901 when he delivered the manuscript. The reason for this belief lies in the fewness and in the character of the papers he left when he died—there was practically no *Nachlass*. And yet he was known to be working on a program of publication. I know this because of the conversation I had with him in June, 1902, when I

was leaving for Paris for a year's study. It was by far the longest conversation I ever had with him, and of course the last. He said that he did not wish to determine my line of future interest but that he hoped I would consider taking some work in applied mathematics in Paris in addition to any I might take in pure mathematics. He ventured the opinion that one good use to which anybody might put a superior training in pure mathematics was to the study of the problems set us by nature. He remarked that in the thirty years of his professorship of mathematical physics he had had but a half-dozen students adequately prepared to follow his lectures. He did me the honor to include me in the list, though I myself never felt that my preparation in physics had been adequate. I asked why he had given exclusively such advanced courses, why he had not offered some more elementary work to prepare his students. He replied that he had not felt called upon to do so but that if I were willing he would be glad to have me look forward to giving upon my return a general introductory course on mathematical physics, and at any rate he would be happy if I would bear the possibility in mind while abroad. He then went on to say that if I should choose to occupy myself somewhat seriously with mathematical physics he had a considerable number of problems on which he thought I could make progress and that he would be glad to talk about them on my return. How much I have regretted that he did not talk of them at the time, but he gave no inkling of them.

Finally he proceeded to say something of his own plans for the future. He remarked that if he could depend on living to be as old as Methuselah he would continue to study for several hundred years yet, but that as he could not except any such span of years he had decided to set about preparing some matters for publication. There were

Reduction to Canonical Form
with the appropriate terms

$$(\phi - aI)^p (\phi - bI)^q (\phi - cI)^r \dots \phi = 0 \quad \text{Hence - Canonical}$$

$$\text{Set } \psi = \phi - aI \quad (\phi - bI)^q (\phi - cI)^r \dots = A\psi^q + B\psi^{q-1} + \dots + L\psi^{q-p}$$

$$\psi^p (AI + B\psi + C\psi^2 + \dots) = 0 \quad \text{Hence, Canc. } A \neq 0$$

$$\text{Set } (aI + b\psi + \dots + k\psi^{p-1})(AI + B\psi + \dots + L\psi^{q-p}) = I + P\psi^p + \dots$$

This might be expressed

$$aI + b\psi + k\psi^{p-1} = \left(\frac{I}{AI + B\psi + \dots + L\psi^{q-p}} \right) / k, \psi^p$$

$$\text{Let } I_2 = (aI + b\psi + \dots + k\psi^{p-1})(AI + B\psi + \dots + L\psi^{q-p})$$

$$= I + P\psi^p + Q\psi^{p+1} + \dots + T\psi^{q-1}$$

$$I_2^2 = I_2 \quad (\text{multi together the two values of } I_2)$$

Form also in same analogy I_1, I_c

$$I_2 I_1 = 0$$

It remains to prove that $\sum I_i = I$
We might have assumed or proved possible
this

$I = \sum Q_i (\phi - bI)^q (\phi - cI)^r \dots$ Q_i being polynomials in ϕ
of degree $p-1$. (This is a common algebraic transfor-
mation.) This gives $I = \sum I_i$ since $I_i = \psi^p Q_i$

~~But it remains to be proved that it is true. Hence - Canc. of all~~

A PAGE OF LECTURE NOTES IN GIBBS' HAND FROM HIS COURSE ON
MULTIPLE ALGEBRA

three lines of activity he desired to pursue: (1) The revision and extension of his work on thermodynamics, to which he said he had some additions to make covering more recently discovered experimental facts not yet adequately incorporated into the theory and other additions of theory apparently

not yet exemplified in experiment. (2) A contribution to multiple algebra on which he said he had some ideas he thought worth while even though the subject appeared at the time not to be of much interest to mathematicians, most of whom were devoting their attention to analysis. (3) A revision of

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Ms A Sept 26 1902

Dear Lord Kelvin.

Your problem of the 'circular atom' in the paper which you kindly sent me some time ago, for which I have since seen in the Phil. Mag. & Proc. Roy. Soc. [Vol XVII p 1140] has given me a good deal of trouble. I cannot get the same result as you.

It seems to me that if the probability that the velocity of an uncaged atom taken at random lies between v & $v+dv$ is represented by

$$Ae^{-v^2} dv,$$

the probability that the velocity of a taken at random when entering the cage lies between the same limits will be represented by

$$Be^{-v^2} dv,$$

where $A+B$ are constants determined by the necessary relations

$$A \int_0^\infty e^{-v^2} dv = 1, \quad B \int_0^\infty v e^{-v^2} dv = 1.$$

FIRST DRAFT OF A LETTER TO LORD KELVIN

DATED SEPTEMBER 26, 1902, PROBABLY FROM INTERVALE, NEW HAMPSHIRE. THIS SEEMS TO DEAL WITH A PAPER WHICH WAS QUITE A SHOCK TO GIBBS AS I KNOW FROM A LETTER HE WROTE ME TO CAMBRIDGE ASKING IF I WOULD LOOK THE MATTER UP IN HARVARD LIBRARY AND REPORT TO HIM. I LOOKED IT UP, BUT MY REPORT WAS SURELY USELESS; THE SUBJECT WAS DIFFICULT AND HE WAS LEANING ON A QUITE TOO SLENDER REED.

his method of computing orbits which should certainly be revised now that it had recently been printed verbatim by Buchholz in the third edition of Klinkerfues' "Astronomy" when certain important improvements were only too obvious. He asked what I should think he

had best first undertake, but without waiting for reply answered that the astronomers were conservative and unlikely to be appreciative of improvements in his methods for orbits, that the mathematicians were not impatient to learn of his ideas in multiple algebra and that on

the whole he felt it was more important to set about the work in thermodynamics to which he had made no published contribution of significance for about twenty-five years.

Ten months later, in April, 1903, Gibbs died. There were found among his papers some chapter headings and the first beginnings of text on the revision and extension of his thermodynamic work. It was clear that what he intended to accomplish he carried in his head and not on paper. We shall never know what he had in mind in any of the three lines of activity. He waited and studied too long. This situation is primarily that on which I base my opinion that he wrote the "Statistical Mechanics" out of his head in something like nine months in addition to his regular teaching. The task was serious. All through the winter and spring of 1900-01 he worked not only by day—the light in his study in Sloane could be seen burning at night. The manuscript was finished in the summer at Intervale, New Hampshire. After Gibbs died, A. W. Phillips told me that it was this severe work that killed him. He said that they had gone together to the express office to dispatch the copy to Scribner's, that up to that time Gibbs had been quite himself, but that from the time they turned away from the office he slumped, the elasticity was gone from his gait, he was a worn-out old man, and never fully came back.

This is a thrilling story, but sad. However, it may not be true. I communicated it to my old friend Ralph Van Name, nephew of Willard Gibbs, who writes: "This may be true, but it was not apparent to his family," and later:

... my comment on the incident of the delivery of the manuscript of the "Statistical Mechanics" was not made in a spirit of criticism, but merely as a statement of my recollection, and of that of my sister, whom I had consulted about it. Though both of us were in

Europe at the time of Willard Gibbs' death, I did not leave New Haven until June, 1902, and she not until March, 1903. It is unquestionably true that my uncle worked to the limit of his strength in trying to get the volume finished on time, and that he did not get over the effort for a good while. But both of us have the impression that he seemed to be in practically normal health and spirits by the Autumn of 1901. . . . My uncle's final illness was a sudden and acute attack of a nature which has no obvious connection with his overwork two years before—it was an intestinal obstruction which the doctors were unable to relieve.

I may say that all through the academic year 1901-2 Gibbs seemed to me to be in normal condition, and in his conversation of June, 1902, of which I have given so long an account seemed to be looking cheerfully and healthily ahead with real pleasure in the prospect which he was outlining and with no discernible feeling that it might not be finished—indeed he spoke as one surely counting on being active on my return fifteen months later.

If I have gone at such length into this story I have done so chiefly because it so well illustrates stories which come with the best intention of truth from persons near to Gibbs, with just as high desires to tell the truth and nothing but the truth as I have on this occasion, but which none the less can not be wholly credited, quite as I do not wholly credit as fact my own statements. There is the story that at home, where he lived all his life with his sister, who had married his friend and classmate, Addison Van Name, he always insisted on mixing the salad, on the ground that he was a better authority than the others on the equilibrium of heterogeneous substances. A very pretty conceit, and one vouched for by a colleague much closer to Gibbs than I, but I daresay both the fact and the statement of reason for the fact would not be substantiated by the family. Another story refers to his letter to *Nature* in comment on and disproof of Lord Kelvin's proposed experi-

ment to determine the velocity of longitudinal waves in the ether. It is said that when a colleague told him that he had just seen the letter in print Gibbs blushed and said that he could not believe the editor of *Nature* would print it. That illustrates his modest and retiring disposition, which was a conspicuous trait, but seems hardly credible.

One often hears lament at Yale and elsewhere that Gibbs' colleagues did not capitalize his great discoveries in physical chemistry by developing the subject experimentally and intensively in New Haven from 1876 on. The comment often takes the turn of wondering how much greater rôle American science would have played in the growth of physical chemistry if Gibbs had accepted the offer to go to the Johns Hopkins University instead of remaining at Yale. How much difference would it have made? Perhaps very little. What efforts Gibbs made to develop physical chemistry at Yale I do not know; perhaps none. That he knew his thermodynamic work was important and knew so when he printed it I have no doubt; but I have noted above that he appeared not to have lectured upon it in his cycle of courses for about fifteen years after its completion, preferring for some reason to teach other subjects,—and the subject-matter of the memoir is not such as would be likely to diffuse around any university without exposition by the master unless by chance there were at hand some almost equally competent person who very much needed the work as a basis for his own, and knew that he needed it. Gibbs was not an advertiser for personal renown nor a propagandist for science; he was a scholar, scion of an old scholarly family, living before the days when research had been research. Probably he had faith that when the time was ripe for his thermodynamics, the doctrine would spread.

Another beautiful legend is that Gibbs was not appreciated in this

country or at Yale during his life. It is probably true that his name was not well known in the ordinary Yale alumnus before the recent time when his photograph and some eulogy of him were widely circulated to the alumni during a drive for funds. But the efforts which were made to arrange for printing his long and costly paper in the *Transactions* of the Connecticut Academy in 1876-78 were a high testimonial to the faith of his local contemporaries in his work. He was elected to the National Academy at forty, the average age of election being fifty, and only the year after the appearance of the second half of the thermodynamic memoir. In 1881 he received the Rumford Medal from the American Academy of Arts and Sciences, which means that a group of his contemporaries in Boston appreciated promptly and highly his contributions in the field of heat. Of course he did not have the notice which Einstein receives to-day; he had no press agents and surely wanted none. There seems to be every evidence that he received the type of recognition to be expected.

Whether the establishment of the Gibbs Lectureship by the American Mathematical Society should be ranked as one of the honors to his memory or whether it belongs with the circularizing of his photograph to Yale alumni as an attempt to get something through exploiting his name I will not venture an opinion. It is well known that this society through all of its life has been chiefly in control of those interested chiefly in research in pure mathematics. It is also well known that the group of American students who went to Germany to study mathematics in the late 'eighties and early 'nineties, at the very time when Klein was emphasizing the need in Germany of a greater attention to applied mathematics, came back to this country with a determination to promote only pure mathematics. This may have been

wise at the time. American mathematicians had been too exclusively interested in the applications. We needed emphasis, perhaps temporarily over-emphasis on pure theory and rigorous procedures, on analysis as it had developed in Europe. The lengths to which this emphasis was carried may be illustrated by my telling a story which happened not so long ago. When E. W. Brown, a past president of this society, was at last naturalized as an American citizen and thus became eligible for election to our National Academy of Sciences, I asked one of the leaders in the section of mathematics of that academy and also a leader in this society whether the mathematicians would not nominate Brown to the academy. He replied in a breezy vernacular "Not till Hell freezes over"—Brown was to him not a mathematician, but Brown was here in good company with Gibbs, G. W. Hill, H. A. Newton, Newcomb and others. Another story shows how non-mathematicians were impressed with the point of view. I once met at the Cosmos Club an eminent expert in international relations who asked why I happened to be in Washington. I replied, "To attend the meeting of the National Academy of Sciences." "But," said he, "you are a mathematician not a scientist," and added, "oh, yes, I remember now that it is an academy of the sciences and of mathematics."

The mathematician has a dilemma, a choice. In so far as he turns his attention to the abstract theory of his subject he is not a scientist dealing with observed fact but a philosopher playing with *a priori* hypotheses. It is only when he turns his attention to applied mathematics that he becomes a scientist. With the obvious need of specialization to-day, I would not limit the choice of the individual mathematician; he should be free to follow his bent or the exigencies of the institution he serves. A great national mathematical society, however, should not limit its interests,

it should cover the whole field of mathematics both pure and applied. In doing so it puts itself right on the pinnacle of intellectual effort. There is no problem requiring more brains, sounder judgment, better total adjustment internal and external, than that of uniting the logical and operational techniques of pure mathematics with the infinite variety of observable fact which Nature offers to our contemplation with a ringing challenge to our best abilities. It was in this field that Gibbs was supreme. He had studied with Weierstrass and was not unmindful of mathematical rigor; in the paper in which he pointed out that phenomenon of the convergence of Fourier Series, which has come to be known as the Gibbs phenomenon, he showed his appreciation of mathematical precision as he did on other occasions. But fundamentally he was not interested in rigor for itself, he was inspired by the greater problem of the union between reflective analytical thought and the world of fact. He did not feel that one should not study pure mathematics; he was not one-sided or dogmatic in any of his views. What he said was that *one* of the uses of a good mathematical background was in the study of the problems set us by nature. And if I had one special inference to draw from my contact with him to give you to-day it would be that the American Mathematical Society should follow for its own good his judgment on that matter. There are indeed indications that times are somewhat changing and that in the future the mathematics in which you as a society are interested will be all mathematics, pure and applied. When that time comes there will be no possibility of raising the query as to whether the Gibbs Lectureship may be only lip service to a great name, for it will be evident that the thought of this society is itself in no

small measure a constant testimonial to that great thinker, J. Willard Gibbs.

You may be somewhat disappointed that I have no very striking personal reminiscences to recount, but what should you really expect in the way of impressions gained by an immature young fellow in the early twenties of a mature quiet scholar forty years his senior. Gibbs was not a freak, he had no striking ways, he was a kindly dignified gentleman. I came to his courses in the days prior to tutorial systems

when students were not expected to take the time of their teachers outside the classroom for personal contact and when teachers did not feel a moral urge to guide their students otherwise than by instruction given in course. I am not sure but this was better for both student and teacher even if it has resulted in a less picturesque address to-day than the one which some now twenty-year old at the California Institute of Technology could give thirty years hence about Millikan.

ANIMAL PARASITES OF WILD AND DOMESTIC MAMMALS AND THEIR RELATIONSHIP TO HUMAN WELFARE

By Professor ERNEST CARROLL FAUST

THE PARASITOLOGY LABORATORY, DEPARTMENT OF TROPICAL MEDICINE,
TULANE UNIVERSITY

INTRODUCTION

THERE is substantial evidence favoring the belief that all living organisms have their parasites, from the lowest bacterium, with its bacteriophage, to the highest mammals, including man. These parasites are other organisms which for one reason or another have found it advantageous to lose their identity as self-sufficient independent individuals, and have become associated with a donor organism, called the host. In some instances this host-parasite association is a very temporary one, in which the parasite merely consumes the food which the host has rejected. Thus various tumble-beetles very industriously work over the dung of most mammals and from this dejecta obtain their food supply. However, in doing so, they commonly ingest the eggs or larvae of certain roundworm parasites of the mammals' intestinal tract and themselves come to serve as intermediate hosts of these roundworms. In other cases the parasite is a biting insect or a tick, which applies itself to the mammals' skin, inserts its external mouthparts and draws up a meal of blood. Among certain biting flies and their allies it is only the "deadly female" which is a blood feeder. The amount of blood consumed is very small compared with the total supply of the host, but inconvenience is frequently caused by the injury at the site of the bite. Not infrequently the "saliva" of the insect, which is injected into the wound just before the blood is sucked up, is poisonous to the host and causes local itching and at times a general reaction. Again,

many biting insects inject larval parasites into the blood stream of the host. These larvae mature and give rise to serious diseases, such as the human sleeping sickness of Africa, malaria, yellow fever, dengue, filarial disease, etc. Other insects, such as lice, contaminate with their dejecta the wounds which they make, and in so doing produce typhus fever and relapsing fever.

There are, moreover, large numbers of parasites which have become so intimately associated with their hosts that the condition is an obligatory one for the parasite. Certain flies lay their eggs in wounds or ulcers; others deposit their eggs or larvae under unbroken skin; still others oviposit on food which is swallowed by various mammals. The eggs hatch in these locations, the larvae grow at the expense of the host's body, cause serious injury and frequently produce death. Many parasitic organisms are taken into the body with food or drink and become attached to the intestinal wall of the host, where they proceed to develop and reproduce. Some of these species of parasites taken into the mouth with food migrate from the digestive tract into the liver, lungs, kidneys, muscles, blood or lymph channels, and develop in these remote locations. Another group of parasites, such as the hookworms and the blood-flukes, directly invade the unbroken skin of the host, and after an involved migration through the body come to settle down in the intestinal wall or its adjacent blood supply. All these latter groups of parasites have become so intimately associated with the life of the

host that their condition is an obligatory one; in other words, life is impossible for them without this association.

These illustrations serve to show the wide range of habits of the parasite in relation to its host. It will now be possible to make inquiry into the types of parasites found in wild and domestic mammals.

TYPES OF ANIMAL PARASITES OF MAMMALS

The animals which are found in parasite association with mammals may be grouped into two main divisions, *ectoparasites* and *endoparasites*. The former are essentially all insects and their allies which live on the skin or in its superficial layers. The latter consist of one-celled animals or protozoa, and various types of parasitic worms, as well as certain insects and their allies. The endoparasites live in all of the deeper tissues of the body, but each parasite usually has a preference for certain tissues. In view of the fact that there are tens of thousands of species of parasites of mammals it will be possible to use only certain forms for purposes of illustration.

ECTOPARASITES

This physiological group includes the ticks, mites, lice, fleas, flies, mosquitoes and bugs. With the exception of the filth and flesh flies and the feather lice of birds all these forms are bloodsuckers, i.e., they depend on blood as a source of food for themselves.

Ticks. The tick lives for the greater part of its life closely associated with the ground and only crawls upon and becomes attached to mammals when it is in need of food. Whether it be the larva, the seed tick or the mature tick, it buries its external mouth-parts into the skin of the mammal and proceeds to feed until it is fully engorged, its abdominal wall swelling out to accommodate the ingested blood. In this respect

it is much like a leech, and when the feeding is completed it drops off and becomes dormant. Such a single feeding in the case of certain species of ticks may last for four or five years. Many of these ticks are not especially selective of their host. The writer has found both the castor-bean tick (*Ixodes ricinus*) and the fowl tick (*Argas persicus*) on the following hosts: dog, ox, wild boar, Bactrian camel, hedgehog (*Erinaceus dealbatus*), jungle-fowl (*Gallus indicus*) and the gecko. He has also had personal experience with these two species of ticks. Ordinarily the drain on the blood is minimal and no ill effects are experienced except for temporary pain at the site of puncture. However, certain ticks, such as the Rocky Mountain sheep tick, *Dermacentor andersoni*, secrete a "venom" which produces paralysis in sheep and in children. Furthermore, ticks are responsible for transmitting the following diseases to various mammals: (1) relapsing fever (man); (2) cattle fever of Texas, Africa, Russia, Japan, etc., and related fevers in sheep, horses and dogs; (3) heart-water fever of Southeast Africa (cattle); (4) Rocky Mountain spotted fever (sheep are reservoirs, man becomes seriously ill), and (5) tularaemia (sheep, rabbits, muskrats, man). Diseases such as Texas cattle fever produce jaundice, anemia, malnutrition and frequently death in the host. In cattle this disease renders the animal unsatisfactory either for beef or milk production. The Bureau of Animal Industry of the U. S. Department of Agriculture maintains a rigorous quarantine in the tick-infested areas of the Southern United States, a justifiable procedure, but one which works a great hardship on cattle breeders and shippers. Prevention of tick infection is a most difficult problem. Various "dips" have been used but these are not always effective, since some of the ticks may remain attached to skin folds, particularly where the fur is long.

It need not be pointed out that for man tick-borne relapsing fever, Rocky Mountain spotted fever and tularaemia are very serious diseases and that the mortality in these infections is high.

Mites. Mites are related to ticks but are smaller and have a less leathery skin. There are hundreds of species which trouble mammals. Some of these are incidental or accidental and need not be considered here. There are several species, however, which produce mange and are not only a great aggravation to the unfortunate host, but are particularly detrimental to the production of marketable pelts. The most common of these mange mites is *Sarcoptes scabiei*. It can infest almost any mammal, and while it is most commonly found in the ear-lobes of fur-bearing animals, it also frequently involves the whole skin. Animals in the wild are much less subject to attack from these mites than are those in captivity. Zoological gardens frequently have to contend with epidemics of mange among their primates and cats, and silver fox breeders are frequently confronted with the problem. Sulphureted lanolin oil, rubbed into all affected areas of the infested animal, is the standard remedy. Sarcoptic itch in man is also a serious skin disease, very resistant to treatment. It has not been proved, however, that the human variety is identical with that of other mammals.

The little red chigger, or harvest mite, is a pest to man in the Southern United States. In Japan and Formosa and probably also in the Malay States and Sumatra, certain of these red mites carry an infection known as "river fever," which is very fatal to man. In Japan the mites are commonly found on certain field mice (*Microtus montebelli*), while in Sumatra certain birds harbor them. In Panama the conejo pintado (*Cuniculus paca virgatus*) is a favorite host of these mites.

Lice. There are two kinds of lice,

biting lice and sucking lice. The former are commonly called feather lice, because they are so common amongst the feathers of birds. They are technically known as *mallophaga*. Very few species have been described from mammals. These forms feed on the barbules of feathers of birds and the epidermal scales and oily secretions of mammals. They are of little economic importance in mammals. The sucking lice (*anoplura*), on the other hand, are of immense economic importance. They are confined exclusively to mammals, particularly rats and mice, horses, oxen, pigs, monkeys and man. The human forms, the body louse, head louse and pubic louse, are indicative of the poorest sort of personal hygiene, while the body louse is responsible for the transmission of typhus, trench fever and the commoner types of relapsing fever. Scrubbing of the body with soap-kerosene mixtures in water and delousing of clothing and kennels with live steam are indicated wherever animals become infested.

Fleas. Fleas are mostly objectionable because of their irritating bites. The commonest species are those found associated with rats and mice, dogs and cats, and man. The fleas of rats, of the ground squirrel and of the tarbagan are of medical importance because they transmit plague from rodent to rodent and from rodent to man. Dog and cat fleas transmit the dog tapeworm, *Dipylidium caninum*. All these forms are on the mammalian body only during their brief blood-sucking period, after which they drop to the floor or ground and lay their eggs, which develop into larvae and then pupate, returning to feed only after the pupae have been transformed into adult fleas. Of especial importance in the realm of true parasites is the chigoe flea, a species commonly found in warm climates. These fleas, which parasitize wild and domestic mammals alike, as well as man,

feed on the hosts' blood, after which they copulate and the female burrows under the skin, particularly that of the feet, leaving a small opening through which she lays her eggs. By this time she is as large as a small pea and the surface of the skin becomes bulged up into distinct boil-like heads, which frequently become secondarily infected with bacteria. The treatment consists in removing the females with a sterile needle and cleaning out the wound with an antiseptic such as kerosene.

Flies and their allies. From the point of view of their relations to parasitism these insects may be divided into two groups, (1) the filth and flesh flies and (2) the biting flies. Even flies which are otherwise very closely related may be separated on this basis, as, for example, the ordinary house fly and the stable fly.

Filth and flesh flies are a serious menace to mammals. In the first place, they may introduce bacteria into accidentally contracted wounds and produce a bacterial infection. More serious, however, is the development of larval stages of these worms (maggots) in the mammalian body. In some instances the eggs of the fly may be swallowed as a food contamination, hatch out in the intestine and develop there, producing multiple ulcers. *Gastrophilus equi*, commonly found in horses' skin, is a good example of this type. Maggots from eggs of practically all the filth flies will hatch in the human intestine and produce more or less trouble. In other species the female fly will intentionally lay eggs in wounds (*Sarcophaga* spp.) of mammals or dart against the conjunctiva of the eye (*Chrysomya bezziana*) and deposit eggs. In both these cases the larvae hatch out and feed on the tissues, usually becoming secondarily infected with bacteria. More serious still are the lesions produced by larvae of flies, where the females introduce the eggs or viviparous

young under the skin or in the nasal sinuses. The bots (larvae of *Hypoderma bovis* and related species) are particularly destructive to the skin layers of cattle, deer, etc. The skins of such animals are worthless for use in the industries. *Oestrus ovis* in sheep, goats and related mammals invades the nasal sinuses and develops there, at times even invading the brain. In both wild and domestic mammals these flies are all serious pests. The flesh fly is the cause of great suffering in wounds of man on the battlefield. Wherever man is closely associated with mammals harboring the bot or sheep maggots and other destructive fly larvae, he, too, may become infested in a similar manner.

Under the group of biting flies and their allies there is a very large number of species with varied life histories, which have in common the custom of sucking blood. There are the common stable fly (*Muscina stabulans*), the horse flies (tabanids), *Chrysops*, the tse-tse flies (*Glossina* spp.) of Africa, and many others which belong to the larger species. Then there are the many hundreds of species of mosquitoes, the sandflies (*Phlebotomus* spp.), the midges (*Culicoides* spp.) and the black flies or buffalo gnats (*Simulium* spp.). The females of all these smaller forms suck blood, and, while the blood of birds is equally acceptable, mammalian donors are usually more available.

In the large, the irritation produced by the bites of flies is incalculable. When it is remembered, however, that many of these flies transmit diseases which are far more serious than their bites, the economic importance of this group will be appreciated. Just to mention a few of the diseases, we may note the following: sleeping sickness of man in Africa, and the trypanosomiasis in wild and domestic mammals; all the known species of filarial infection in man and mammals; yellow fever, dengue, sand-fly fever, and tularaemia. The im-

portance of these transmitters in human medicine is just beginning to be appreciated; their significance in the causation of disease in wild mammals is still unfathomed.

Bugs. Many bugs will bite mammals on provocation, but most of these bites are accidental. However, the bedbug and its allies are dependent on blood-sucking as a source of food. Likewise the assassin-bug and the "kissing-bug" belong to this latter category. The bedbug has been accused of transmitting an Oriental disease known as kala-azar, also certain spirochetel infections, but there is no definite proof incriminating this much-maligned creature as a necessary agent either in these or other diseases. The assassin-bug (*Triatoma megista*) is known to be the transmitting agent of Chagas disease to man in South America. The armadillo is the wild reservoir of this infection.

ENDOPARASITES

Endoparasites have been defined as those organisms which live parasitically for a greater part of their life within the body of their host. For convenience they may be considered under the following headings: (1) protozoa or one-celled organisms, (2) flatworms and (3) roundworms. There are so many thousands of these species that only a few can be considered.

Protozoa. Some of these lowly parasites are primitive and simple in their structure; others are complex and specialized. Among the former are the endamebas, while in the latter group are the malarial organisms.

The endamebas. These species live primarily in the digestive tract. Some live entirely in the intestinal lumen and feed only on food as it passes through the intestine. One type (*Endamoeba gingivalis*) is found associated with bacteria and spirochetes in pyorrheal infections of the gums. Another, *Endamoeba histolytica*, is a tissue parasite

and causes definite ulcers in the large bowel. This latter species is common to man, several species of monkeys, the cat, the dog, the rat and the pig. In man it frequently produces dysentery.

Flagellates. There are two physiological groups of endoparasitic flagellates, those in the intestine and those in the blood stream and blood-forming organs. The former group are relatively innocuous; the latter are usually pathogenic. Among the latter are the dozens of species of trypanosomes, causing diseases in wild animals, also in cattle, horses, donkeys, sheep, camels, monkeys and man (sleeping sickness). Then there are the modified hemoflagellates (leishmanias) which cause cutaneous and visceral diseases in man and dogs.

Malarial parasites and related forms. There are three distinct species of malarial infection in man. In monkeys there are several types of malarial parasites. Other mammals also harbor parasites of this group, but it seems altogether likely that they are all distinct one from another. The piroplasms, anaplasms, etc., which infect red blood cells, are not known to infect man but constitute a serious group of infections in cattle, sheep, horses, camels, etc. Coccidia infest rabbits, sheep, cattle, hogs, dogs and cats and occasionally develop in man. Most of these coccidia are located in the walls of the intestines but in rabbits they infest the liver. Horses and cattle, camels and sheep are at times afflicted with a protozoan infection of the flesh known as *Sarcocystis*, and man has been reported to have incurred this disease.

Ciliates. There are several ciliated protozoa which live in the intestinal tract of mammals. Some of these are located in the stomachs of ruminants. The most widely known species, *Balanidium coli*, is a parasite of the large bowel of the hog, monkey and man. In man, at least, it is at times associated with a severe dysentery.

Flatworms. These forms consist of two types, tapeworms and flukes.

Tapeworms. There are many hundreds of species of tapeworms infesting mammals. The majority of these occur as adult, sexually mature forms attached to the intestinal wall of their host, but in some cases they are found in the larval state in other organs of the body. All species of mammals have tapeworms. Some of these worms are only a few millimeters in length while others are several meters long. The adult *Echinococcus* in the dog's intestine is an example of the first type; the human beef tapeworm, of the second type. In most instances the infection does not cause serious inconvenience to the host, but at times intestinal upsets, nervous disorders and profound anemias are attributed to these worms. All the tapeworms, with the exception of some of the dwarf species (*Hymenolepis* spp.), require at least one intermediate host. In many forms one mammal serves as the adult host and another as the larval or intermediate host. The following will serve as examples: *Taenia hydatigena*, dog (adult), ox, sheep, goat, pig (larval); *Taenia ovis*, dog (adult), sheep, goat (larval); *Taenia pisiformis*, dog (adult), rabbits (larval); *Taenia taeniformis*, cat (adult), rat (larval); *Taenia multiceps*, dog (adult), sheep, goat, ox, horse (larval); *Taenia serialis*, dog (adult), rabbit (larval); *Echinococcus granulosus*, dog (adult), sheep, ox, pig, man (larval). It will be seen from this series how important the dog is in spreading these infections, in which the larva is a far more serious pathogene than the adult worm.

Flukes. These worms are interesting but peculiar forms. All those found in mammals require some snail as a first intermediate host and some species require a second intermediate host as well. In certain types the mammal incurs the infection from consumption of herbage

containing the larvae which have crawled out of their snail hosts and become encysted. This accounts for most of the fluke infections of cattle, sheep, hogs, camels, etc. Other mammals, such as dogs and cats and their wild relatives, beavers, martens, and man—all piscivorous animals—become infected from consumption of infested raw fish. The lung-fluke of wild felines, the pig, the dog and man is accounted for by consumption of infested raw crabs and crayfishes. The blood-flukes of horses, cattle, sheep, camels, mice and man invade the mammalian skin in their larval stage and migrate to the portal blood vessels.

Roundworms. The roundworms in mammals are legion. While the majority of them are found in the digestive tract, some important groups get into the muscles; others live in the blood and lymph spaces; still others have a predilection for the lungs, kidneys, etc. Most of these species have relatively simple life histories, but some require intermediate hosts. Those which get into the body via the mouth are introduced as a contamination of food or drink; those which use the skin as a portal of entry are usually introduced by the bite of a fly.¹ The "stomach-worm" (*Ascaris*), the whipworm and the pinworm are examples of the former type, while the filarial infections are representative of the latter type. The guinea-worm is an example of a most interesting type. It enters passively by accidental ingestion of water-fleas (*Cyclops* spp.) parasitized by the mature larval stage of the worm, and emerges through a skin puncture made by the gravid female worm at the time she is ready to discharge her progeny of wriggling larvae.

GENERAL CONSIDERATIONS

It may be inferred from a consideration of the foregoing types of animal

¹ The hookworm and related species constitute exceptions to this rule.

parasites of mammals that there is no strict line of cleavage between those forms found associated with wild mammals and those associated with mammals under domestication. Since all mammals were originally in the wild state and since parasitism undoubtedly antedates all known records, it is safe to assume that wild mammals were parasitized even at the time when they were emerging from their more lowly ancestors. Those species of parasites which have reached the nearest equilibrium with the tissues of their host, i.e., those which cause least damage to the host, are possibly the forms that became associated earliest in this host-parasite relationship.

Undoubtedly in the past, as at present, epidemics with parasites have wiped out entire species of wild animals or have, at least, limited their distribution. However, animals in confinement are much more liable to infections of this kind. Man has acquired his animal parasites in three ways: (1) by eating the raw flesh of wild or domestic animals harboring the larval stage of the infection; (2) by skin and mouth contamination with stages of the parasite from mammalian sources, and (3) by insect bites, causing the introduction of parasites which have come from mammals to man. Of course many animal parasites of one host have failed to become adapted to other hosts exposed to infection. This fact has kept these infections more or less within limits. Likewise, certain species of parasites, while retaining their structural identity, have become physiologically different in different hosts, so that the parasite of one host is not interchangeable with that of another. This fact also tends to keep these infections within bounds.

Immunity reactions of mammals to animal parasites are much less complete

than they are to bacteria. In fact, it seems likely that there is no complete immunity of any mammal to any animal parasite, although certain individuals manifest a partial immunity to malaria, to *Ascaris* infection and to hookworm infection. A relative age immunity has developed in the case of *Ascaris* in dogs, in that of the strongyle, *Haemonchus*, in sheep, and of the dwarf tapeworms in rodents and man.

The economic loss occasioned by animal parasite infections of mammals in the wild, in zoological gardens, and in cattle, sheep, pig and horse-breeding localities amounts to a physical drain on natural resources which is far greater than any intrinsic value that might be placed on it. Likewise, in human welfare, the illness and incapacity for work due to malaria, hookworm disease and other animal-parasite infection is too great and too wide-spread to be measured by monetary standards. Prevention of these infections requires, first of all, a knowledge of the life cycles of all the species of parasites involved; likewise, acquaintance with the weak points in the life cycle where the parasite may be most easily attacked. In the next place, it is necessary to utilize such methods as will be most practicable. Theoretically, the avoidance of contamination with infested excreta and screening from insects are the most common general methods of attack. Mass therapy is also an important line of procedure. Quarantine measures are designed to stop the spread of infections. Here, again, the problem can be solved only by an intimate acquaintance with the specific merits of the case.

From both a physiological and a practical view-point the animal infections of mammals constitute one of the most engaging group of problems in present-day zoology or medicine.

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COLD PREVENTIVE WORK AT CORNELL UNIVERSITY

By Dr. D. F. SMILEY and Dr. G. F. MAUGHAN

DEPARTMENT OF HYGIENE DEPARTMENT OF PHYSIOLOGY
CORNELL UNIVERSITY

THE common cold and its complications has been the main disease cause of disability among our student body throughout the eighteen years for which figures are available. And the peak of the cold curve has invariably occurred each year sometime during the months of December, January, February or March.¹ In certain of these months, colds and their complications have been so frequent as to make up well over one quarter of the calls made upon our ten college physicians for advice or treatment.

The magnitude of the cold problem among the male students of Cornell

University is somewhat shown in the accompanying chart (Chart 1).

Small wonder then that the prevention of colds has taken on for us something more than an academic interest!

THE COLD EPIDEMIC LIMITED TO A SMALL GROUP

In 1924 a questionnaire study² of 2,485 freshmen and sophomores showed the following distribution of colds according to frequency:

	Group 1, No cold or 1 a year	Group 2, 2 or 3 a year	Group 3, 4 or more a year
Men, per cent.	15.4	58.2	26.2
Women, per cent.	18.8	61.3	19.5
Average	17	60	23

In 1926 a similar questionnaire study³ of 1,625 freshmen and sophomores showed the following distribution of colds according to frequency:

	Groups 1 and 2, Never more than 3 colds a year	Group 3, 4 or more a year
Men, per cent.	72.5	27.5
Women, per cent.	76.1	23.9
Average	74.3	25.7

Throughout the period, November 1, 1926, to April 3, 1927, we recorded the incidence of colds among 1,625 students who had classified themselves as having either three or less colds a year, or four

² "A Study of the Acute Infections of the Throat and Respiratory System," *J. A. M. A.*, 82, 540-541, February 16, 1924.

³ "A Study of the Weekly Incidence of Colds in Normal and in Cold susceptible Groups throughout a Winter," *Am. J. Hygiene*, ix, 2, 477-479, March, 1929.

CHART 1
RELATIVE NUMBER OF ACUTE INFECTIONS* OF
THROAT AND RESPIRATORY SYSTEM
FOR SPECIFIED YEARS

	Total consultations	Consultations for acute respiratory or throat infections	
		Number	Per cent.
1919-1920.....	13,619	2,392	17.4
1920-1921.....	13,280	1,475	11.0
1921-1922.....	16,655	2,409	14.4
1922-1923.....	16,832	2,894	17.2
1923-1924.....	17,852	2,453	13.7
1924-1925.....	21,360	3,057	14.3
1925-1926.....	18,798	3,614	19.2
1926-1927.....	16,999	2,714	15.9
1927-1928.....	18,913	3,177	16.7
1928-1929.....	17,306	3,035	17.5
1929-1930.....	15,256	2,116	13.8

* Diseases listed as acute infections of throat and respiratory system: "influenza" (cold and fever), Vincent's angina, acute rhinitis, acute bronchitis, acute pleurisy, acute tonsillitis, acute pharyngitis, acute otitis media, peritonsillar abscess, acute tracheitis, pneumonia and acute sinusitis.

¹ "Seasonal Factors in the Incidence of the Acute Respiratory Infections," *Am. J. Hygiene*, vi, 5, 621-626, September, 1926.

or more colds a year. Among the 468 normal (not more than three colds a year) women students and 732 normal men students throughout the twenty-two weeks in which colds were recorded, there was no week when more than 13 per cent. of the groups had a cold and no week when less than 3 per cent. had a cold. Among the 147 cold-susceptible women students and the 278 cold-susceptible men students, there were weeks when 60 to 62 per cent. of the groups had a cold and there was no week when less than 19 per cent. of the group had a cold.

A study⁴ of the 815 male members of the entering class, in the fall of 1927, showed that 17.9 per cent. of them were cold susceptible (had four or more colds a year) and that same group had averaged 4.31 infectious diseases per person by college entrance as against an average of 3.68 infectious diseases per person, among the normal (never more than three colds a year) group.

From the above data we have concluded that there is one group of students (17.9 to 27.5 per cent.) who are unduly susceptible to all infectious diseases and particularly so to colds. And, furthermore, it is in this group we believe that our winter epidemics of colds occur, since the curve of colds in the normal group is flat and practically devoid of any epidemic peak.

THE COLD EPIDEMIC, ENTIRELY A WINTER PHENOMENON

For the past 18 years there has been no winter when our student body has escaped having an epidemic of colds sometime during the dark, cold period between December 1 and March 31, though the peak for the year 1920-1921 was a very slight one.¹ There are many conditions which obtain in our student body during this winter period which do

⁴ "Cold-susceptibles vs. Normals, Physique and Past Medical History," *Am. J. Hygiene*, ix, 2, 473-476, March, 1929.

not obtain during the summer and which might quite conceivably lower the resistance of our cold-susceptible group *en masse*. The atmosphere of our lecture halls and recitation rooms throughout the winter months is apt to be hot, dry, quiet and considerably polluted by infective moisture droplets talked, coughed or sneezed out of the many throats. Windows are opened here and there and adequate mechanical systems of ventilation are in operation in a few of the more modern buildings, but in order to keep the feet warm and comfortable through the hour, the average lecturer or instructor has found that windows can be opened only very conservatively, if at all. Thus at the end of the hour the student not infrequently steps out abruptly from a classroom with a temperature of 70° Fahrenheit and a relative humidity of 25 per cent. into an outside atmosphere with a temperature of zero Fahrenheit and a relative humidity of 70 per cent. This marked difference in atmospheric conditions, the New York State Commission on Ventilation found, results in a paling, a swelling and non-resistant condition of the mucous membrane of the nose, as well as in a decrease in the mobilization powers of the "immune bodies" in the blood stream. A charting of cold incidence at Cornell against average temperature, month for month throughout the period, 1912-1913 to 1924-1925, showed a definite reciprocal relationship between the two.¹

In spite of our earnest efforts to popularize the use of the "protective foodstuffs," such as milk, leafy vegetables and citrous fruits, a large number of college students still fail to include adequate amounts of these foods in their daily diet. As a result, it is not uncommon to find the alkaline reserve at a point we would consider low or low-normal. And when in mid-winter the vegetables they do eat are largely canned ones and the milk comes

only from stall-fed cows, and the eggs from winter-housed chickens, a deficiency in vitamin intake sufficient to lower resistance to many types of infection is almost certain to occur.

The part that a high blood sugar plays in lowering resistance to colds is still not determined, but the frequency with which colds follow "candy sprees" in children and adults at Christmas time is at least suggestive.

A skin that receives little, if any, sunlight tends to become pale, rough and very sensitive to changes of temperature in the air about it. In such a skin very little vitamin D is formed from the irradiated ergosterol. Lack of sunlight in the dark winter months may, therefore, keep the skin hypersensitive to chilling and contribute to the vitamin deficiency, thus conceivably lowering the resistance to colds in two ways. A checking of cold incidence at Cornell against average hours of sunshine, month for month through the period 1912-1913 to 1924-1925, showed a definite reciprocal relationship between the two.¹

We have, therefore, been led to conclude that some of the important factors responsible for the cold epidemics among our cold-susceptible students are faulty ventilation, faulty diet and lack of ultra-violet irradiation of the skin surface.

PREVIOUS ATTEMPTS AT CONTROL OF COLD EPIDEMICS

A large number of the experiments designed to control just one of the cold-causative factors enumerated above have given surprisingly favorable results. Thus the New York State Commission on Ventilation reports a uniformly decreased incidence of colds among school children whose school-rooms are ventilated by the modern modified window method rather than by the mechanical method. Several workers report a decreased incidence of colds

where the children's attention is rather continuously called through "no-cold campaigns" to such hygienic faults as sneezing or coughing with the mouth uncovered by a handkerchief. Other workers report that diets rich in the "protective food-stuffs," and particularly in butter, are very successful in reducing the incidence of colds. Dr. V. S. Cheney, of Chicago, states that it is frequently possible to prevent the occurrence of threatening colds by appropriate doses of alkali. At Cornell^{5,6} through two winters, 1926-1927 and 1927-1928, groups of cold-susceptible students were given weekly irradiations of ultra-violet light which corresponded roughly with the amount of ultra-violet light which the average student would obtain from the sun's rays on his neck, face, hands and wrists in ordinary clothing in midsummer. The incidence of colds in the groups so irradiated was approximately 40 per cent. less than in similar groups of cold-susceptible students which were being followed but not irradiated.

PRESENT ATTEMPT AT CONTROL OF COLD EPIDEMICS

Beginning with the fall of 1929, the following measures were put into operation:

(1) Each freshman receives in his hygiene course as full an explanation as we can provide as to the importance of controlling the condition of the indoor air through proper regulation of heat and open windows, as to the importance of treating nose and throat secretions as extremely infective materials and as to the importance of including in the daily diet two to four glasses of milk, two helpings of leafy or fiber vegetables, one

⁵ "The Effect of General Irradiation with Ultra-violet Light upon the Frequency of Colds," *J. Prev. Med.*, ii, 1, January, 1928.

⁶ "Irradiations from a Quartz-mercury Vapor Lamp as a Factor in the Control of Common Colds," *Am. J. Hygiene*, ix, 2, 466-472, March, 1929.

helping of fruit, one or two salads, and very little candy or sweets.

(2) All those students who classify themselves as cold-susceptible (usually having colds four or more times a year) are urged to pay a nominal fee and join a "cold-prevention class," there to receive the following treatment:

(A) A fifteen-minute ultra-violet light bath is given once a week from October through December, twice a week from January through March, once a week again through April. (Solaria using Everready Sunshine carbon arcs, General Electric Type S1 lamps, and Cooper-Hewitt mercury arcs in corex D glass tubes and accommodating 150 students per hour have been installed.)

(B) Since we found that the alkaline reserve in a group of cold susceptibles was in many cases lower than that in a group of cold immunes, we have been issuing to the cold susceptibles joining the class one ounce packages of a powder composed of equal parts of sodium bicarbonate and magnesium carbonate flavored with oil of peppermint, with the directions to "take one teaspoonful in a glass of water twice a day for three days whenever the nose runs or the throat feels sore."

(C) In those persons whose colds continue to occur in spite of the above régime a careful study of the nose, throat and sinuses is made. Where a chronic sinusitis exists with the nose structurally normal, an antogenous vaccine is made up and given subcutaneously in 1 cc doses once a week through the year. Where sinuses, nose and throat seem normal, a mixed stock catarrhal vaccine is given in 1 cc doses once a week for a varying period. Where nasal obstruction, empyema of sinuses or chronic infection of tonsils demand it, operation is advised.

(D) A sheet of specific instructions concerning diet, alkalization, ventilation, sleep and ultra-violet irradiation is given each member of the class.

RESULTS IN COLD-SUSCEPTIBLE GROUP TREATED

Each week during the period of treatment, each member of the cold-prevention class fills out a slip printed as follows:

Date _____

Name _____

Have you had a cold during the past week?

Yes _____

No _____

If "yes" was it mild _____?

Severe _____?

Each week also a control group of similar cold susceptibles, untreated and simply under observation in a weekly hygiene class, fills out a similar slip. The results, November, 1929, through January, 1930, were as follows:

	Total number of colds	Number mild colds	Number severe colds	Number colds apiece
100 cold-susceptible students under treatment	115	84	31	1.15
38 cold-susceptible male students untreated	76	54	22	2.00
Per cent. reduction, 42.5				

The results, February, 1930, through April, 1930, were as follows:

	Total number of colds	Number with continuous colds	Number with no colds	Number of colds apiece
98 cold-susceptible male students under treatment	99	2	33	1.01
33 cold-susceptible male students untreated	80	2	2	2.42
Per cent. reduction, 58.26				

¹ "Further Observations on Control of Common Colds by Ultra-violet Rays," *Brit. J. Actinotherapy and Physiotherapy*, v, 6, 115, September, 1930.

COMMENT

The work so far has had to be largely limited to the male students, since the women students have not shown sufficient interest to pay the nominal fee and take the treatments in numbers large enough to be significant. Reasons for this may be, first, that women are not so much troubled by colds; second, it is possible that the women students object to the necessity of taking the treatments nude, even though in their own solarium operated by women and located in the women's medical adviser's office.

The results we obtained in the small group of women who joined the "cold-prevention class," February, 1930, through April, 1930, were as follows:

	Total number of colds	Number with continuous colds	Number with no colds	Number of colds apiece
15 cold-susceptible female students under treatment	26	1	3	1.73
6 cold-susceptible female students untreated	13	0	0	2.16
Per cent. reduction, 19.9				

To expect at this early stage of the organized work (it is now only in its third term) to note a measurable reduction in the colds of the whole student

body is to be too optimistic. If, however, we could popularize our "cold-prevention class" to the point where they would include 1,000 to 1,200 of our cold susceptibles instead of merely 150 to 300 of them, we have good theoretical grounds for believing that the cold epidemics in the whole student body would be considerably modified.

CONCLUSIONS

(1) Colds and their complications are our commonest disease cause of student disability.

(2) Cold epidemics occur largely in the 17.9 to 27.5 per cent. of students definitely cold susceptible and touch very little the normally resistant group.

(3) A combination of old and new methods applied to groups of cold-susceptible male students in our hands has resulted in a reduction of 42½ to 58.26 per cent. in cold incidence.

(4) Difficulty has been encountered in getting the cooperation of women students and in the very small group of cold-susceptible women who have joined the "cold-prevention class" a reduction of only 19.9 per cent. in cold incidence was noted in the first experiment.

(5) We have theoretical grounds for believing that attacking the colds in the cold-susceptible group will prove to be an effective way of modifying or averting the usual cold epidemics of our student body. We have as yet no positive evidence to present in confirmation of this belief.

PALMS OF THE CONTINENTAL UNITED STATES

By Dr. JOHN K. SMALL

NEW YORK BOTANICAL GARDEN

ALTHOUGH millions of people outside of the tropics are acquainted with palms, their acquaintance is limited largely to potted plants; and it is not, as one may well believe, under such circumstances that palms reveal themselves to be what they have so properly been termed: "Princes of the vegetable kingdom." While there are many kinds, it is true, that develop well in large greenhouses, most of the specimens grown indoors are puny; or even if well developed, their surroundings so detract from their true characteristics that much of their natural beauty is lost.

Only in the tropics or in the outlying areas of natural distribution in temperate regions, where nature has planted them and given them a chance to grow, either singly or *en masse*, does one get the true idea of the majesty of this unique and highly characteristic group of plants.

During the later geologic ages palms grew in most parts of North America, as is shown by the fossils preserved in the strata of the continent. Remains of the various organs, mostly leaves, have been found not only in temperate North America, but also as far north of the Arctic Circle as collectors have thus far penetrated. Owing chiefly to the firm substance of their tissues, moreover, the minutiae of some of these ancient palms have been preserved to us in the greatest detail. These palms of the North occurred mostly, if not wholly, in the later geologic ages, being most abundantly preserved in the strata of the Tertiary period, although they definitely appeared, developed and multiplied in the preceding period, the Cretaceous.

Palms were thus, apparently, much more widely distributed over the face of the earth in past geologic times than at present, but the number of different kinds living at any one time, perhaps, did not rival the aggregate existing today, which is approximately twelve hundred species. About the same number of species as are now living in the continental United States are recorded for the past ages by the fossil remains from all parts of North America.

In modern times there are two main centers of geographic distribution for palms—tropical America and tropical Asia. There is a minor center in tropical Africa.

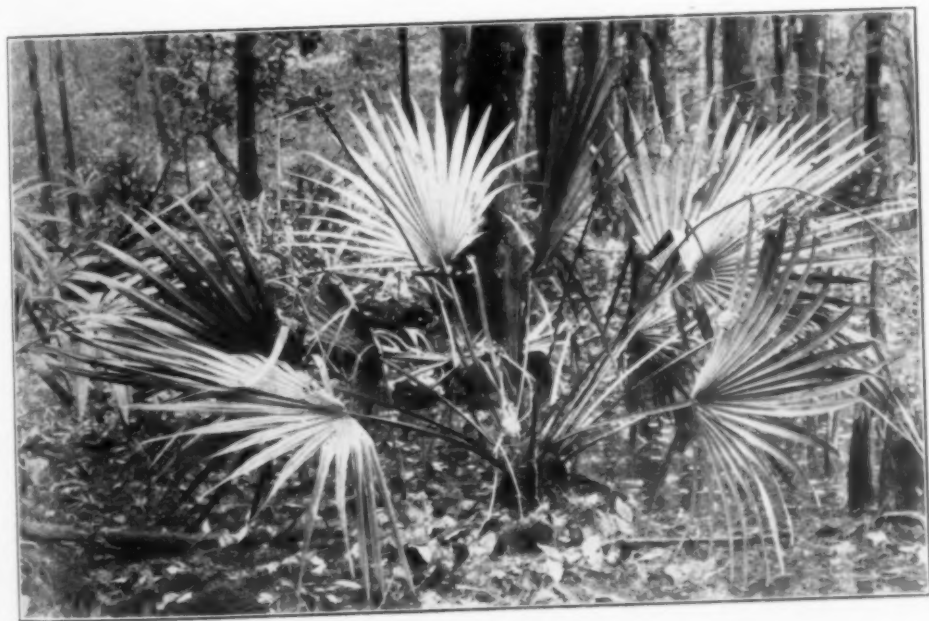
Instead of extending into the present arctic regions as they formerly did, the northern geographic limits are now in the southern United States, southern Europe, Afghanistan and southern Japan, while the southern limit in America is about middle Chile, or, in other words, the geographic distribution is within 38° north latitude and 37° south latitude, in regions with an average temperature of 60° Fahrenheit or more, and a minimum rarely, if ever, below zero.

If palms were wide-spread in North America up to the ice ages, they were then pushed southward, perhaps beyond their present northern limits, for they may have regained some of the territory since the retreat of the ice. In origin palms were likely tropical. Hence those that populated temperate North America migrated northward. The ancestors of those now on the Atlantic seaboard would naturally have come from the West Indian region while those of the present



CABBAGE TREE (*SABAL PALMETTO*)

GROWING IN SAND AND FORMING A CABBAGE HAMMOCK ON INDIAN PRAIRIE WEST OF LAKE OKEECHOOEE, FLORIDA.



BLUE STEM (*SABAL MINOR*)

GROWING IN ALLUVIUM IN SWAMP ALONG LITTLE RIVER, NORTHERN FLORIDA



NEEDLE PALM (*RHAPIDOPHYLLUM HYSTRIX*)

GROWING IN ALLUVIUM IN LITTLE RIVER SWAMP, NORTHERN FLORIDA.

Californian species would have come through Mexico. However, there is one palm mystery with us—the needle palm. The present relatives of this unique palm are on the opposite side of the globe. This condition, however, is not altogether unusual, for there are several herbaceous and woody plants in the flora of our Southeastern states thus isolated. A record of the geologic, meteoric and biologic changes in the great hiatus during which such fundamental changes took place would be most instructive and entertaining.¹

COCONUT PALM—*Cocos nucifera*.

BUCCANEER PALM, HOG-CABBAGE PALM, SARGENT PALM—*Pseudophoenix vinifera*.

ROYAL PALM—*Roystonea regia*.

DATE PALM—*Phoenix dactylifera*.

CABBAGE TREE, CABBAGE PALMETTO, CABBAGE PALM, TREE PALMETTO, SWAMP PALMETTO—*Sabal Palmetto*.

JAMES' PALMETTO—*Sabal Jamesiana*.

¹ The following list gives the botanical names of the palms of the continental United States and their equivalent common names. The latter are used throughout this article.

PALMETTO PALM, TEXAN PALMETTO, TEXAS CABBAGE TREE—*Sabal texana*.

SCRUB PALMETTO, SAND-HILL PALMETTO—*Sabal Etonia*.

BLUE STEM, DWARF PALMETTO—*Sabal minor*.

PALMETTO-WITH-A-STEM, BAYOU PALMETTO—*Sabal Deeringiana*.

SAW PALMETTO—*Serenoa repens*.

FANLEAF PALM, DESERT PALM, WASHINGTON PALM—*Washingtonia filifera*.

SILK-TOP THATCH—*Thrinax parviflora*.

BRITTLE THATCH—*Thrinax microcarpa*.

SILVER PALM—*Coccothrinax argentea*.

SAW-CABBAGE PALM, SPANISH-TOP, CUBAN PALM—*Paurotis Wrightii*.

NEEDLE PALM, BLUE PALMETTO—*Rhapidophyllum hystrix*.

The history of the palms of the continental United States covers more than four centuries. The earliest reference seems to be embodied in the "Rio de las Palmas" on the map of Alberto Cantino.² This Rio de las Palmas is with-

² Though to the famous Ponce de León goes the credit of being the first European to land on the shores of the North American continent, we are confronted with two ancient and authentic maps, one dated 1502 and a second 1508, eleven and again five years before 1513 when

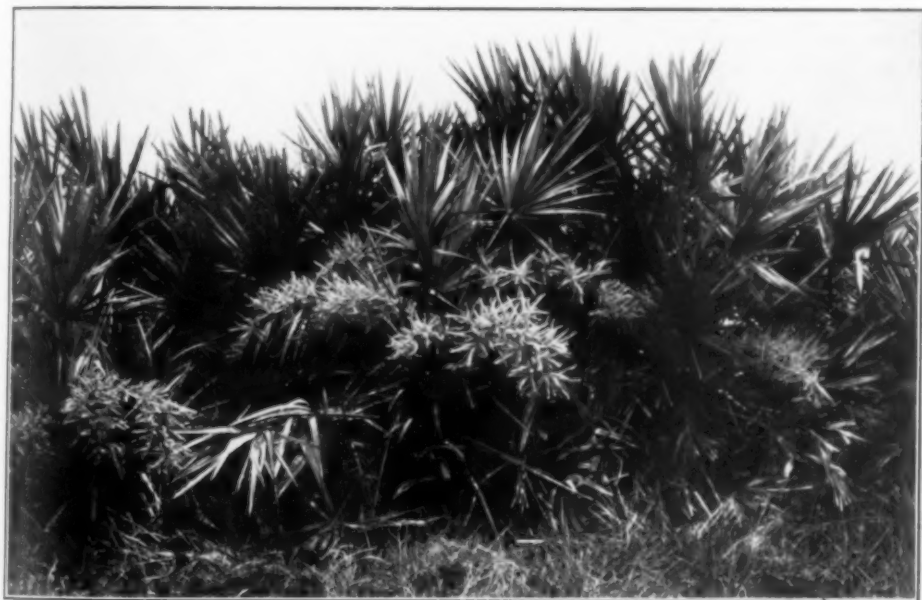
out much doubt intended to represent the now international Rio Grande. If this is so, the palmetto palm or Texan cabbage tree, would be the first of our palms to be referred to, though indirectly. On the other hand, the latest native genus to come to light within our boundaries was the saw-cabbage palm, which was discovered in southern Florida as recently as 1888.

There seems to have been little recorded concerning North American palms, at least in English literature, between 1500 and 1700. After the beginning of the eighteenth century references to these plants became more numerous, and the following palms were added to

the famous knight of Léon arrived in search of the Fountain of Eternal Youth. Some one, name, nationality, and date unknown, had previously made a voyage to the coast of Mexico, around Florida and up the Atlantic Coast as evidenced by the oldest map, dated 1502, known as the Alberto Cantino map.—*Robert Ranson.*

our recorded flora in the order cited—saw palmetto, royal palm, fanleaf palm, needle palm, coconut, silver palm, thatch palm, buccaneer palm, saw-cabbage palm and date palm.

To-day seventeen different kinds of palms are known to grow naturally in the continental United States—four feather palms and thirteen fan palms. The former group seems to represent a more primitive type, at least as indicated by the structure of the leaf, in which the divisions are arranged along the sides of an elongate axis or rachis. This group includes four of our palms. Arranged in their biological sequence, they are buccaneer or hog-cabbage, coconut, royal and date palms. In the fan palms the leaf axis or rachis beyond the petiole is wholly or partly lost. In this case there are no separate divisions of the leaf, but there is a blade with the veins arising palmately from the tip of the petiole or pseudopalmately (or subpin-



SAW PALMETTO (*SERENOA REPENS*)

WITH PROSTRATE-CREEPING STEMS, GROWING ON COASTAL SAND-DUNES, CAPE CANAVERAL REGION, FLORIDA.



SAW PALMETTO (*SERENOA REPENS*)
WITH ERECT STEMS, GROWING IN SAND IN PINE-
LANDS, EAST OF TAMPA BAY, FLORIDA.

nately) from the more or less abbreviated midrib, which represents the remains of the rachis of the leaves of the pinnate type, and prolonged into lobes or segments beyond the body of the blade. Consequently the fan palms may be classed into two groups which may be designated, Palmatae and Pinnati-palmatae. The latter group embraces the cabbage trees or palmettos, the fanleaf, the saw-cabbage and the needle palms. The former group, or that of the truly palmate or flabellate palms, comprises the saw palmetto, the thatch and the silver palms.

The geographic distribution of the living palms of the United States is almost identical with that of the flowering epiphytes or air plants. The state of Virginia, however, is not invaded by the palms, while Arkansas in the East and California in the West must be added to the credit of the palms alone. The geo-

graphic distribution may be briefly stated thus: the southeastern United States in Arkansas, Louisiana and Texas, and in southern California. In considering the geographic distribution of the palms in relation to the various states, it is understood, of course, that the political areas are not usually made on the basis of biologic or geologic boundaries. However, they are definite and well fixed in people's minds and serve to indicate latitudinal and longitudinal distribution. It may be of interest to record here that our palms are naturally confined to the Atlantic and the Gulf Coastal plains with two minor exceptions. These will be referred to further on.

The most northern locality for living native palms in North America is Cape Hatteras, North Carolina, although the palm region in southern California is a close second.

In modern times, palms would probably be able to grow naturally farther



DATE PALM (*PHOENIX DACTYLIFERA*)
WITH A COCONUT PALM AT LEFT, GROWING IN
SAND AND MARL ALONG BAY BISCAVNE, FLORIDA.

northward along the Atlantic coast if it were not for the abrupt angle in the coast line of North Carolina. Between Georgia and Cape Hatteras the coast line runs in a northeasterly direction, so that the coastal sands and dunes have a warm southeastern exposure. At a point about thirty miles north of Cape Hatteras, however, the coast line turns abruptly to the northwest, and thus north of the Hatteras region the shore has a northeastern exposure. Consequently a great deal of the warmth derived from the angle of the sun's rays on the land south of Cape Hatteras, as well as the



SILVER PALM (*COCCOTHRINAX ARGENTEA*)

MATURE, GROWING ON OOLITIC LIMESTONE IN PINE-PALM LANDS OF BIG PINE KEY, FLORIDA.



SILK-TOP THATCH (*THRINAX PARVIFLORA*)

GROWING ON CORAL LIMESTONE IN HAMMOCK ON RACHEL KEY, FLORIDA.

effect of the warm air from the great expanse of heated water lying between the coasts of the Carolinas and the Gulf Stream and the West Indies, is lost to the coastal region north of Cape Hatteras. Although only on the edge of one of the major palm regions, the following notes on the palm association of the southern United States will be a revelation to some and of interest to many plant lovers.

Taking up the geographic distribution by states, we find that the only palms known to grow naturally in North Carolina are the cabbage tree and the blue stem. Passing southward, we find the same species repeated in South Carolina and also two additional ones in the extreme southern part of that State. The latter are the needle palm and the saw palmetto. In Georgia are found the same four palms that occur in South Carolina. To sum up: there are four different

COCONUT PALM (*COCOS NUCIFERA*)

GROWING IN GROOVE IN SAND ALONG BAY BISCAYNE, FLORIDA.

palms, the cabbage tree, the blue stem, the needle palm, and the saw palmetto, together representing three genera, in the Atlantic Coastal Plain north of Florida.

The cabbage tree now ranges farther north than any other of our species. Curiously enough, however, it is absent from the Gulf Coast westward of Saint Andrew's Bay, Florida, although conditions along the Gulf of Mexico seem to be favorable for its growth, at least nearly or quite as much so as those that obtain along the Atlantic Coast north of Florida. Its absence from the Gulf Coast may be occasioned by cold storms that sweep down through the Mississippi Valley, where there is less high land and no mountain chains to temper them as there are back of the Atlantic seaboard.

However, this well-marked, north-south extension of range may be the result of the passage of migratory birds, plus favorable temperature and other climatic conditions. Peninsular Florida is, and perhaps was formerly, at least in recent geologic time, the center of the geographic distribution of the cabbage trees. The general course of flight of

migratory birds is north and south and not east and west. Birds may have carried the seeds of this palm northward. Although they may retain seeds in their alimentary canal but a short time, year after year they may have carried the seed farther and farther northward in the Coastal Plain. By slow stages of progress the palm could thus have gradually accommodated itself to a cooler and more changeable climate until it reached its limit of endurance at Cape Hatteras. This seemed good theory even when it was still pure supposition, but recently an actual case of the migration of two of our native palms has come to our notice. Thus, the northern geographic limit of the silver palm until lately was in the vicinity of the Miami River on the Everglade Keys in southern peninsular Florida, but within the past relatively few years the northern limit has actually been extended over seventy miles, or more than a hundred miles northward of its Floridian center of development.

The fruits of this palm are black and meaty, and are esteemed as food not only by various birds but by other animals as

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well. When a coastwise navigation canal was dredged northward from the upper end of Bay Biscayne, sand banks were thrown up on one side or another of the waterway. These banks, undisturbed, soon became clothed with herbs, shrubs and trees, as a result of the various methods of seed dispersal, representing both local plants and those foreign to the region. Among the latter is the silver palm, found on the embankments and apparently nowhere else in the region. Thus, it is fair to believe that the migratory birds bringing the seeds northward, either follow the course of the inland waterway closely in their flight, or that seeds dropped in neighboring parts where there is little country suitable for their growth do not germinate or, at least, do not survive after germination.

Closely following this, another equally interesting discovery was made. The silk-top thatch was found growing in the

dense tropical plant association on the coastal dunes between Delray and Palm Beach. These palms had attained no great size—apparently of recent introduction, their advent there was evidently due to the agency of birds. The sand-dune hammocks along the entire eastern coast of Florida are exceedingly interesting and as yet but little explored and studied. In some places the woody vegetation is wind-worn and sand-worn; in other places, especially on aboriginal villiage sites not directly exposed to the ocean, many of the trees are of great size. That birds and also mammals plant seeds of their food plants thereabouts is evidenced by the palms, figs, cacti, and various berry-bearing shrubs that spring up and survive for a time on the large horizontal limbs and in decaying knot-holes remote from the source of supply of their seeds.

Of course the higher latitude is against



SILVER PALM (*COCCOTHRINAX ARGENTEA*)

JUVENILE, GROWING IN SAND, MIAMI, FLORIDA.



ROYAL PALM (*ROYSTONEA REGIA*)

GROWING IN MARL IN ROYAL-PALM HAMMOCK IN
THE BIG CYPRESS SWAMP, FLORIDA.

the natural development of this tender tropical palm northward, but the tempering effects of the canal, the lagoons, the marshes, and the nearby ocean, although they are slight, may be sufficient to enable the palm growing directly on the warm banks to survive the cold spells of the winters.

On the other hand, some of our palms are retreating to a highly circumscribed area. Take the royal palm for an example. William Bartram found this palm far "up" (really down) the Saint John's River—between Lake George and Lake Dexter—shortly after the middle of the eighteenth century, for he records that:

The palm trees here seem to be of a different species from the cabbage tree; their straight trunks are sixty, eighty, or ninety feet high, with a beautiful taper, of a bright ash colour, until within six or seven feet of the top, where

it is a fine green colour, crowned with an orb of rich green plumed leaves.

To-day there are no royal palms growing naturally within two hundred and fifty miles of Bartram's recorded locality. Furthermore, during the "freezes" of 1894 and 1895, the three isolated royal palms growing in a hammock in the Big Cypress Swamp near the settlement of Everglades were killed, and the species thus exterminated in that immediate region by the wiping out of the colony.

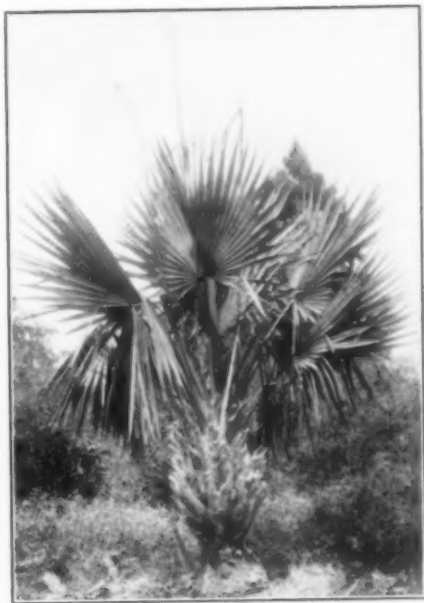
Before considering our palm *El Dorado* we will approach it by another route, from west to east. Thus, taking up the Gulf States and beginning at the western extremity of the range: In Texas, as in the case of North Carolina, we first find a cabbage tree—the pal-



BUCCANEER PALM (*PSEUDOPHOENIX
VINIFERA*)

GROWING ON CORAL LIMESTONE IN HAMMOCK OF
ELLIOTTS KEY, FLORIDA.

metto palm or Texas cabbage tree—in the extreme southern tip of the state. This palm represents the southern limit of distribution in the western Gulf States, just as its relative the cabbage tree represents the northern limit of distribution in the Atlantic States. Farther north in the Coastal Plain of Texas the blue stem, which was also associated with a cabbage tree in North Carolina, appears. In all, there are then but two palms native in Texas. In Louisiana the number of species is three; the palmetto palm has dropped out, and the palmetto-with-a-stem or the bayou palmetto is associated with the blue stem, and the saw palmetto appears east of the Mississippi River. The blue stem occurs also in southeastern Arkansas.



PALMETTO-WITH-A-STEM (*SABAL DEERINGIANA*)

GROWING IN GUMBO IN SWAMP ALONG LAKE PONTCHARTRAIN, LOUISIANA.



BRITTLE THATCH (*THRINAX MICROCARPA*)

GROWING ON OOLITIC LIMESTONE IN PINE-PALM LANDS ON BIG PINE KEY, FLORIDA.

Passing eastward from the delta of the Mississippi River, the blue stem and the saw palmetto are retained and thus the State of Mississippi, like its neighbor, Alabama, has three kinds of palms, the blue stem, the needle palm and the saw palmetto.

Here it is interesting to notice that we find the only exception in the eastern states to palms occurring outside the Coastal Plain. The first and second palms—the blue stem and the needle palm just mentioned—occur a little way north of the fall line in Alabama, while the blue stem extends over on the edge of the Edwards Plateau in Texas. These extra-limital, so to speak, cases of distribution are interesting when we realize that with these exceptions the palms not only are confined to the Coastal Plain, but that they, for the most part, grow in the lower parts of that region.

PALMETTO PALM (*SABAL TEXANA*)

GROWING IN CLAY AND FORMING A GROVE ALONG THE LOWER RIO GRANDE, TEXAS.

One state in the East remains to be considered; it is both an Atlantic state and a Gulf state, namely, Florida. In fact floristically it is largely "a law unto itself" among the contiguous states. It is no wonder that Florida with its unique geographic position and long peninsula, flanked on both sides by vast bodies of warm water, and whose southern extremity is situated farther south than any other part of the continental United States and continuously bathed with the tropical waters of the Gulf Stream, is naturally and preeminently the State of Palms. For the same reasons, it is the banner state for the epiphytic ferns, as well as for the flowering air plants. Within its boundaries may be found every palm already mentioned, except the palmetto palm and the bayou palmetto, and in addition, ten other species. All the species of palms within the geographic limits covered by this article but two are native. The coconut palm was introduced into Flor-

ida after its advent in the New World through the agency of the early Spanish expeditioners, either through natural or artificial channels, while the date palm has been introduced through cultivation and the scattering of seeds. Of the eight native genera, one—the needle palm—is limited to the southeastern United States, while seven others have species growing naturally in the West Indies. Curiously enough, none of the species growing naturally in Florida occur in the continental tropics, except the now widely distributed and extensively cultivated coconut palm.

The following coincidence is interesting: In the case of the flowering air plants, whose geographic distribution is almost identical with that of the palms in the eastern United States, all except one endemic species of southern Texas occur in Florida; likewise all the species of palms in the eastern United States except one endemic kind in southern Texas and also one in Louisiana, occur

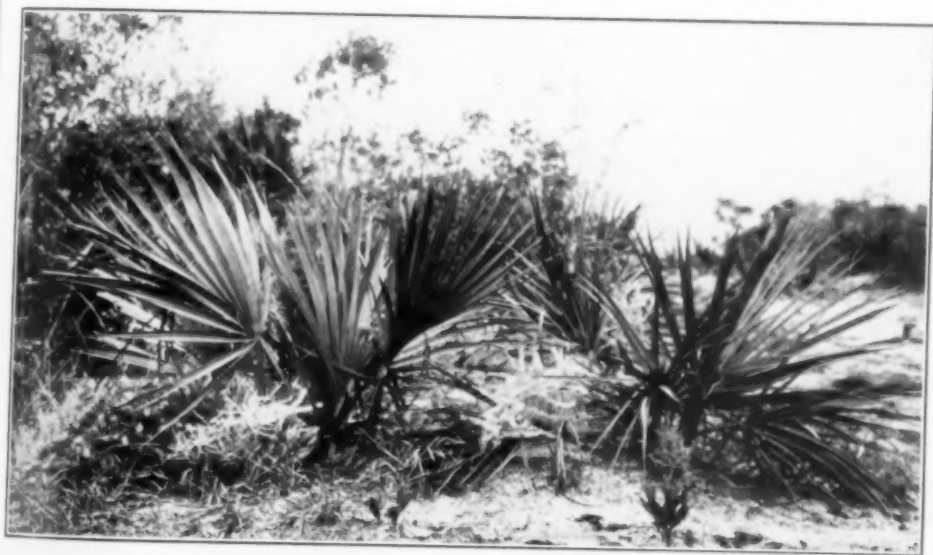
in Florida! Furthermore, the palms, like the epiphytes, are evergreen.

Two of the species—the needle palm and the blue stem—that grow in other states occur only in northern Florida and in the northern part of the peninsula, while the other two—the cabbage tree and the saw palmetto—extend southward not only to the end of the peninsula, but beyond it to the lower Florida Keys, as recent exploration has demonstrated. The endemic species of Florida are the scrub palmetto and the James' palmetto. The former occurs from the northern part of the lake region to the southern part of the peninsula, while the latter ranges from the Everglade Keys to the southern end of the lake region.

The other eight species that do not grow naturally north of Florida are confined to the tropical and adjacent subtropical parts of the State. They are the silk-top thatch, the brittle thatch, and the silver, the saw-cabbage, the royal, the hog-cabbage, the coconut and the date palms.

The hog-cabbage palm has of late years been erroneously reported as exterminated in Florida. It grows naturally also on the other side of the Gulf Stream, both in the Bahamas and on the Cuban Keys, and it has rather recently been rediscovered in Santo Domingo.

Among the other five native species the two thatch palms and the silver palm grow both on the Florida Keys and on the nearby mainland, but nearly or quite within the bounds of the tropical region. The saw-cabbage and the royal palms do not grow naturally on the Florida Keys, but occur in the tropical portion of the peninsula and the adjacent subtropical parts south of a line between Arch Creek on the Atlantic Coast and Cape Romano on the Gulf Coast. Whether the geographic distribution of the royal palm is wholly or only in part natural will be discussed further on; but it may be said in passing that it is evidently native in most places where it is now found; although in a few localities it may have been introduced by the



SCRUB PALMETTO (*SABAL ETONIA*)

GROWING IN SAND AND SCATTERED OVER THE SANDHILLS OF THE LAKE REGION, FLORIDA.

JAMES' PALMETTO (*SABAL JAMESII*)

GROWING IN SAND IN HAMMOCK ON THE EVERGLADE KEYS, FLORIDA.

aborigines before the coming of the white man.

The remaining palms to be considered grow in a region far distant from that already described; they are the fanleaf or desert palms of the Pacific slope.³ These plants are the only conspicuous exception in the parallel of the geographic distribution of the palms of the United States and that of the flowering epiphytes.

Following is a list of the palms of North America north of the West Indies

³ Apparently only one of these palms is native in California. The second known species, *W. robusta*, native in Lower California, is extensively cultivated in southern California and may be naturalized there. *W. filifera*, or perhaps a third species, has been discovered in western Arizona.

and of Mexico, with indications of their geographic distribution and uses:

COCONUT PALM—Southern Florida—Native of Polynesia and the East Indian Archipelago, whence it was brought to the western coast of Tropical America and established perhaps within half a century after the discovery of the New World by Columbus. Now widely naturalized in the tropics. Extensively introduced into southern Florida in the earlier part of the second half of the past century. Cultivated in many parts of the tropics for its fibers, fruits, and oil, and for ornament.

BUCCANEER PALM, HOG-CABBAGE PALM, SARGENT PALM—Upper Florida Keys (W. I.). Cultivated for ornament. Stems used as food for animals. The sap was formerly converted into an alcoholic drink. The fruits are used for fattening hogs. The bud is edible.

ROYAL PALM—Southern peninsular Florida: perhaps formerly more widely distributed in the peninsula (W. I.). Cultivated for ornament. The spathes are employed for packing or wrapping various objects. The fruits are used for fattening hogs.

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DATE PALM—Southern Florida. Introduced from Africa and Asia where it has been cultivated from prehistoric times. The tree figured in symbolism, the fruits furnished a staple food, and the leaves ecclesiastical paraphernalia. It is grown in Florida for ornament and occasionally for food.

CABBAGE TREE, CABBAGE PALMETTO, CABBAGE PALM, TREE PALMETTO, SWAMP PALMETTO—North Carolina, South Carolina, Georgia, Florida (W. I.). Cultivated for ornament. Bud used for food. Leaf fibers woven into braid for making hats and rope. Stems used for timbers, posts and piles. The leaves are commonly employed as a thatch.

JAMES' PALMETTO—Southern peninsular Florida (Endemic). Occasionally planted for ornament. The fruits are eaten by birds and mammals.

PALMETTO PALM, TEXAN PALMETTO, TEXAS CABBAGE TREE—Southern Texas (Endemic). Uses same as those of *Sabal Palmetto*.

SCRUB PALMETTO—Peninsular Florida (Endemic). Bud used for food. Fruits eaten by hogs.

BLUE STEM, DWARF PALMETTO—North Carolina, South Carolina, Georgia, Arkansas, Texas, Louisiana, Mississippi, Alabama, Florida (Limited to the United States). Cultivated for ornament. Leaf fiber woven into braid for making hats. Leaves are used for thatch and are eaten by cattle. Hogs eat the fruits.

PALMETTO-WITH-A-STEM, BAYOU PALMETTO—Southern Louisiana (Endemic). Occasionally planted for ornament. The leaves are used for decorations. The fruits are eaten by birds and mammals.

SAW PALMETTO—South Carolina, Georgia, Texas(?), Louisiana, Mississippi, Alabama, Florida (Limited to the United States). Stems a source of tannic acid; also used for making brushes. The leaves are prepared for decorative purposes. The fruits are used medicinally and for making a popular drink. They are much sought after by hogs and formerly were a staple food of the aborigines. The bud is edible.

FANLEAF PALM, DESERT PALM, WASHINGTON PALM—Southern California (Lower California). Cultivated in America and Europe for ornament. Stem used for timber, contains also much salt and sugar. Fruits are used for food by Indians.

SILK-TOP THATCH, THATCH PALM—Southern Florida (W. I.). Cultivated for ornament. Leaf fiber woven into braid for making hats. Stems used in construction. The leaves of this and the following species of *Thrinax* are prepared for indoor decorations.

BRITTLE THATCH—Southern Florida (W. I.). Cultivated for ornament. Leaf fiber woven into braid for making hats. Stems used for construction.

SILVER PALM, SILVER-THATCH PALM—Southern Florida, geographic range increasing (W. I.). Cultivated for ornament. Stems locally used for construction.

SAW-CABBAGE PALM, SPANISH TOP, CURAN PALM—Southern peninsular Florida (W. I.). Cultivated for ornament. Stems used in construction.

NEEDLE PALM, BLUE PALMETTO—South Carolina, Georgia, Alabama, Mississippi, Florida (Confined to the United States). Sometimes cultivated for ornament.

In addition to the above cited uses, the fruits of all our palms are food for various birds and mammals. The leaves, too, are gathered and shipped to distant points for symbols in traditional ecclesiastical ceremonies, applicable both to the living and to the dead, inherited directly or indirectly from ancient pagan peoples.

Considering their relative conspicuousness, our native palms were slow in securing recognition in our botanical records. The only palms now growing wild in the United States known to Linnaeus were the coconut and the date palms, both, however, introduced plants. Two additional ones came to the attention of European botanists or European plant collectors as early as the beginning of the last century, and, curiously enough, only these four were known to botanists as late as the seventies of the nineteenth century. Even as late as 1880 a note in the "Botany of California" states that only "four species of

"Botany of California." Ed. 2. 2: 1880. The authors of that work were ignorant of any of our pinnate-leaved palms, for they wrote: "The United States genera all belong to the group *Coryphinae* or *Sabalinae*, distinguished by their fan-shaped leaves and perfect flowers." The coconut palm had evidently been known in southern Florida for many years previous. The genus *Roystonea* was definitely discovered there about three years previous to the publication of the work in question, while



WASHINGTON PALM (*WASHINGTONIA FILIFERA*)

JUVENILE, GROWING IN GRANITIC SOIL IN GROVE OF A THOUSAND PALMS NEAR INDIO, CALIFORNIA.

palms are found on the Atlantic coast"—of course, meaning the Atlantic seaboard.

During the last decade of the nineteenth century, exploration in southern Florida brought additional species to light, so that now we know definitely of sixteen different kinds of palms growing without cultivation in the Coastal Plain between Cape Hatteras, in North Carolina, and the mouth of the Rio Grande in Texas. The additional palm or the seventeenth species is the fanleaf palm of California. Although the Pacific

the third pinnate-leaved palm, *Pseudophoenix*, was not discovered in Florida until six years after its publication.

slope can claim only one native palm, it can boast of the largest—the giant of our palms. The royal palm in the East may rival the fanleaf palm in the West in height, but it lacks the massiveness of the trunk.

The origin of our native palms is an interesting problem. On the Atlantic side of the continent the genera *Pseudophoenix*, *Roystonea*, *Sabal*, *Thrinax*, *Coccothrinax*, and *Paurotis* indicate an Antillean origin, while on the Pacific side *Washingtonia* is related to Mexican and Pacific forms. The two endemic genera, represented by the saw palmetto and the needle palm, are especially interesting. The former is related to Antillean types, while the relatives of *Rhaphidophyllum* are far off on the shores of Asia. In structure and habit it is unique in our flora. It is a repre-



SAW-CABBAGE PALM (*PAUROTIS WRIGHTII*)

GROWING IN MARL IN HAMMOCK ALONG CUTHBERT LAKE, CAPE SABLE REGION, FLORIDA.

representative of an ancient and apparently now largely extinct arrangement of plants in which its sometime associates, *Tamion taxifolium*, *Taxus floridana*, and *Crocomia panicflora* flourished, but which to-day exist as mere remnants among a strange plant association with their closest relatives thousands of miles away.

Truly this is a notable representation of an aristocratic family among plants.

primarily tropical, flourishing in a region where temperate, mild conditions prevail. A group of plants whose timber, foliage, fruits and sap in themselves are sufficient for supplying the necessities, shelter, clothing, food and drink for a primitive people. Likewise, the palms, if not a necessity to a civilized people, furnish many objects of convenience and derivatives of great utility.

MODERN YOUTH AND THE RESEARCH SPIRIT

By Professor J. O. HERTZLER

UNIVERSITY OF NEBRASKA

I

THE tempo of modern life is breath-taking. Kaleidoscopic changes are occurring, and unsettling developments confront us continually. Our material civilization is ever changing. New social needs and problems are evident on every hand. Cherished and long-standing social, ethical, economic and political view-points and institutions are being criticized and modified or even abandoned. The world of arts and the spiritual life are in upheaval. New challenges must be faced and new adjustments of all kinds must be made continually if the individual is to be a reasonably intelligent and successful participant in life. There is no place in this modern world for the person who acts only on the basis of instinct, habit and routine or rule of thumb.

Any education worthy of the name, therefore, must consist of more than an accumulation of standardized facts and the acquisition of the contemporary culture. We are also beginning to see that it should give more than the mastery of some technique, more than mere preparation for meeting the conventional requirements of life at the moment.

Education to-day must develop the powers that will give the individual facility to use the acquired knowledge and techniques. But he must have not only faculty and versatility; he requires also the *attitudes* that will enable him to get at truth, orient himself to it and apply it in the future by himself. Education must produce a capacity for interpretation that will enable him to make a workable mental and social adjustment to the trends of a changing world. It must awaken in him an in-

sight and an outlook, and prepare him for intellectual pioneering.

Most of the intelligent citizenry and apparently many of the educational authorities as well are unaware of what is happening to our present-day students in the way of making them mere routinists and followers of vocations. The contention of this paper is that our colleges and universities are grievously failing to meet one of their greatest obligations if they do not give the students and, through them, the population at large, the research spirit.

II

This research spirit is the method of thinking and the attitude of science. Of first rank importance in it is the desire to know. The person with the research spirit has a boundless, insatiable curiosity, an abiding passion for facts and for understanding the relationships among them. He does not knowingly traffic with untruth or half-truth, nor what he surmises would destroy truth.

To make this discovery of truth possible several other attitudes are essential. He seeks to develop a meticulous precision of observation, study, thought and statement. To be sure that he is fairly facing all sides he is tolerant, impartial and devoid of sentimentality. He is willing to recognize and examine divergent claims. Dogmatism is foreign to him, and he insists that all that claims to be fact or truth demonstrate its quality in the forum of life.

His attitude is always critical, even skeptical. He never thinks that the evidence is all in. The most important witnesses may still be in waiting, and will continue so till he learns how to call

them in. He questions all dogmas and theories, all precedents and traditions, all solutions and methods until he has had opportunity to examine them or inform himself as fully as possible respecting them. He is somewhat skeptical of all authority and permits himself no sanctities save truth and reality. He is suspicious of strong partisanship, of all that smacks of propaganda, all strenuously pressed claims and sugar-coated ideas. He is critical of all that is old, feeling that it may be static or archaic, and of all that is new because it may be untried or premature. But he will accept either old or new if it meets the tests. With Paul of Tarsus, he would test all things and hold fast that which proves to be good. His is an implicit willingness to follow free inquiry to an unwelcome conclusion.

The individual with the research spirit is composed when confronted by change, however revolutionary it may be; in fact, being mindful that everything is in a state of continual flux, he anticipates change. He adjusts himself without panic or fear, for he knows that the truth that yet lies hidden will be gradually revealed and may, as history lucidly teaches, overturn many or all existing conclusions and methods.

It is a spirit that, while keeping the individual humble before truth, does not permit an attitude of resignation, defeat or indifference. Neither does it allow complacency. Inherent in it is hope of solution and confidence in reason.

Patience is also innate here. Investigation is not hurried along to a conclusion. The best truth available at the moment is deliberately sought. But when he is sure of his truth the worker hesitates not a moment in putting it into effect. For truth is no end in itself, in his opinion, but a means to fulness of life and to social progress.

There is also inherent in the research spirit a discipline which produces facility in analysis, interpretation and con-

clusion. If the individual is without bias and has a sufficiency of truth, he sees fact follow fact in inexorable sequence to an inerrant and inevitable conclusion. He develops a logical method of thought which enables him to penetrate confusion, discover untruth and lay bare facts which he can then use effectively to make an approach to solutions. The individual learns to think clearly, see straight and act with judgment.

Finally the research spirit develops in the individual new powers of imagination and inventiveness. Experience in connecting fact with fact and reasoning from cause to effect enables him to transcend the existing and contemporaneous and pass logically in his mind to the necessary but non-existent, to the next step, even the remote future step. The research ideal stretches the mind and exalts the spirit as it carries man farther on his upward flight. It is the creative spirit.

Thus the research spirit is the philosophical essence of scientific procedure. It is an outlook on life tempered and disciplined by the scientific method of arriving at facts. It is realistic in its approach to problems, yet idealistic and even spiritual in its interpretations and solutions. The writer's thesis is that it offers an eminently desirable, even indispensable, philosophy of life for men at large, but especially for modern youth in this more or less chaotic and disillusioned age. It is not offered as a cure-all, for it is by no means all the young people need. It must also be remembered that not all people engaged in research are models of the research spirit. Some of the most bigoted and mentally insecure persons are scientists of competence in their own special field; but their research spirit is applied *only in that field*. To have its fullest significance the individual must utilize it in *all* his thinking. Itself a by-product of

this age, it is also one of its important remedies.

The writer is a social scientist and has also for twelve years been the teacher, friend and father confessor of university students. What does he see, as he looks out on life, that leads him to think that the research spirit should be developed as far as possible in students to aid them in their life problems?

III

Ours is an intricate mechanical world full of ever-multiplying devices, attachments and appliances. They are increasing the nervous tension and occupational hazards of millions. They touch almost every moment and aspect of our lives, making them more complex and artificial. They have claimed our bodies and our time. Shall they also claim our souls?

This is a shrinking world as well as a mechanical one. The recent developments in transportation and communication have suddenly thrust upon the individual a vast and unprecedented number and variety of culture elements from every corner of the earth. The relocation or breakdown of political boundaries and of economic and racial barriers since the war has also accentuated and brought to the consciousness of the rank and file a whole series of new, danger-laden problems. The individual must withstand the shock of contact with all these new culture elements and problems, choose among them, maintain his mental, moral and spiritual balance and arrive at workable conclusions.

This is also a world that is filling up. The world population has doubled in the last century and is now increasing at an unprecedented rate. This makes social relationships ever more complex and impersonal, and anti-social action becomes easier. It imposes new obligations upon us as consumers of resources, as users of machines and as potential progenitors of future generations. It

causes the division of labor to become more extensive and intricate, increasing the mutual dependence of individuals, classes and nations. Furthermore, as numbers increase in a world of limited area and diminishing returns, international economic rivalry results and from this arises a never-ending series of crises that continually threaten and periodically disturb the peace of the world. To avoid war we need the research spirit above all, for not superficial but final and fundamental remedies must be found that will check it at its source, namely, human reproduction.

In every country modern government has become very complex as it has had to assume new problems. In America, especially, its details have come to be so numerous, so involved and so technical that the average citizen does not and can not know about them. When decisions must be made he takes refuge in his party creed and swallows his party's catchwords and slogans without compunction. Since he thinks little for himself he becomes a fundamentalist in politics, using the doctrines of government established by an agricultural and stage-coach people, and accepting the Constitution in its textual literalness of 1790 and not in its essential interpretations of 1930. He acts on the basis of stereotypes or of a public opinion manufactured by propaganda and counter-propaganda working upon his traditions, prejudices, aversions or his inertia. And finally, if he votes at all, he is usually one of only about 30 per cent. of the citizens entitled to vote. The future success of democracy demands willing, informed and self-possessed citizens, able to penetrate to the bases of political action and capable of participating independently and intelligently.

Because of the absence of an effective public opinion and sound individual information or conviction, and yet being confronted in this democracy by a mass of problems crying for treatment, we

Americans, especially, through our legislators, have taken the easiest way and have resorted to laws as means of coping with them. The consequence is that our laws are so numerous that we can know almost none of them, we have little energy for or interest in enforcing them and have developed a growing disrespect for all laws. Our very plethora of laws has made us lawless.

Because of these problems growing out of the complexity and diversity of modern life, the requirements of social and rational action are more numerous and frequent than ever before. Relatively, however, the tried and established means and materials for coping with them are fewer and less suitable than ever before. Hence, what is needed among the rank and file is a set of attitudes that make us socially alert, that enable us to evaluate social situations and recognize anti-social acts.

IV

The enormous and continuous growth of wealth presents challenges. There now is in America the greatest per capita wealth the world has ever known. But we have so mismanaged as to give unprecedented luxury to a few; we have intensified the struggle for a living, increased our waste and produced a serious unrest.

We have erred in another way. Economic goods have become ends in themselves. Modern business has engaged in ubiquitous advertising, the essence of whose appeal is that you can not be intelligent or progressive unless you purchase every new product on the market and display it. Its maxim seems to be, "Set your hearts on the things of this world." This has made a kind of universal prodigality obligatory among all classes. Spiritual values, true culture, appreciation of real beauty, service of the good, true and abiding cede to the tawdry display of dollar values.

Our machines have given us more leisure than men have ever had before, and yet we apparently have never had less real leisure. Somewhere we have slipped. The machines that have given us free time enable us—almost force us by suggestions, pressures and abnormal mental or physical states—to misuse it. Instead of becoming gods, as science anticipated when it developed these machines and this control, we are becoming slaves.

The research spirit, with the use of historical fact, demonstrates that the dominance of material pursuits eventually devitalizes a society, brutalizes the people and leads to cultural and spiritual death. We have to keep our balance, establish criteria and get back to fundamentals. The spirit of research alone will enable us to distinguish the abiding, the socially and culturally sound from the opulent, the standardized, advertised and futile.

Not only do we live among standardized things, but our minds are subjected to standardized stimuli from radio hookups, newspapers and movies. In addition we have huge national and international organizations such as Kiwanis, Rotary, Lions and Optimists that give us far-reaching, standardized interpretations for the middle classes. We are standardized in our selling, buying and consuming, in our vices and virtues, or joys and sorrows, in leisure and working, politics and religion. We are becoming chain-store articles in almost every respect. What is worse, these standardizing agencies develop in us common feelings, prejudices and fetishes, and then, operating simultaneously among us as they do in our present state of concentrated populations, frequent distractions and lack of privacy and quiet, very easily produce crowd-mindedness among us. We are in danger of becoming marionettes with the strings pulled by syndicating journal-

ists, advertisers, professional uplifters, political spellbinders, evangelists or any one else who can gain the questionable reputation of being an "authority" or the leader of the temporary cult of "the thing." And, of course, as never before, the spinners of intellectual spider webs have their way and work their will upon us.

Especially sinister, in view of the situation just depicted, is the appalling apathy of a large number of our American youth, as well as many older people, in the realm of ideas and ideals. They want to avoid being thought of as "highbrow." They do not seem to be greatly interested in social or public questions, social reform or progress. So many of them swallow or at least accept what is taught them or what comes to them through all these other agencies with despair-provoking readiness. They are willing, nay eager, to conform to a type in the making of which they have done nothing. Many of them actually seem to approve of intellectual mediocrity, credulity and slavish acceptance, and avoid criticizing or holding opinions.

On the other hand, paradoxical as it may seem, the charge that our young people are in revolt can also be sustained. The younger generation in many cases are thoroughgoing critics of almost all conduct codes, customs, conventions and many of our social institutions. Most of these they look upon as time-worn and largely worthless encystments. They take joy in seeing idols smashed and eagerly participate in the process. Above all they want to avoid any appearance of softness or sentimentality in themselves. They want freedom from restraints imposed by earlier generations; they feel the urge to try themselves out in new social situations and strange environments; they yearn to taste the full flavor of their own freely expressed personalities. Along various lines they want a world of less protection and security, more adventure, more

spontaneity, and they do most certainly go their own independent way in getting it.

V

Similarly as a reaction to the long-suppressed disgust with the fool's paradise of the war when everything was propagandized, and unpleasant or ugly facts were either ignored, denied or "dressed-up," we have had and are still having an epidemic of "realism" and "debunking." Some of our institutions, especially marriage and the church, are being challenged; the bourgeoisie have been classified and described in detail; business and advertising, Main Street and Park Avenue are being debunked; in fact, there are few sacred precincts. History has been divested of most of its misguided patriotic twaddle, and many of our great historical personages have been demonstrated to have had so much that was weak, petty and unscrupulous in their characters that, suspended between the old interpretation and the new, we are not sure whether our so-called great were saints or devils. Much of this dispelling of untruth and illusion is necessary, but there are objectionable extremes that must be considered. The sex novels, the "tough" plays, risqué movies and "true story" literature, under the guise of realism and with the aid of abnormal psychologies, have given us unbridled license, and a sickening parade of the pathological, the bizarre, the shocking and the unbalanced.

Real realism is most necessary. One can conceive of nothing worse than a world of well-varnished untruths and sticky sentimentalities inhabited by Pollyannas. Most of us take great joy in the exposure of some wilful misconception or sanctified absurdity. Moreover, a prudish passing by of a bad mess is both cowardly and silly. The veil needs to be lifted, secret evils should be acknowledged and the unlovely realities of

life faced. But instead of a crusade to expose sham our "realism" in so many cases has become "the cult of the seamy side." An honest, sincere, realistic facing of social facts also points to the normal, the wholesome, the sound—even the hopes, the ideals and the spiritual aspects of life—as being equally valid parts of the true picture. Why make life and sewers synonymous? It is essential to see this distinction between realism and the cult of the malodorous and abnormal.

Now no one wants to go back to the musty artificial confines of the Victorian world. At the same time one can not be in a perpetual quagmire of uncertainty or skepticism. Here the research spirit has a peculiar appeal as a dominant intellectual principle. It is realistic in the true sense of the word, for it points to certain inescapable laws and ultimate values that even a lawless and skeptical age learns that it must respect.

VI

Sinister also is the vast stock of nostrums and cure-alls which are offered us for every ill, personal or social, real or imaginary. These are similar to the All-healing Snake Oil ballyhooed by itinerant medicine venders from the back seats of surreys in Ohio towns when the writer was a boy. This great "nature's remedy" would cure everything from bunions to cancer. To-day religious ills may be promptly cured by any one of a dozen new cults. Amends may be made for our neglected health if we confine ourselves to foods with a given vitamin or take some other highly recommended pabulum. There are a dozen near-psychologies that will extricate us from a variety of troublesome neuroses and naughty complexes. A whole collection of panaceas is continually available to solve our social, political and economic problems, especially the major ones, such as crime, poverty and war. For the ills

of nations we have offered sovietism, communism, fascism. Our forgetfulness can be corrected by a half dozen different memory courses, which, if carefully followed, will enable us to remember the names, addresses, telephone numbers, occupations, businesses, church memberships, lodges and luncheon clubs of ten thousand people (Selah). We are likely to grow as wise as Solomon or as cultured as Aristotle by purchasing two dollars' worth of pamphletized books or the famous five-foot shelf. (How the good Dr. Eliot would turn in his grave and groan if he knew what a cure-all had been made of his collection!) Some of these have a modicum of truth about them; others are patent inanities and insanities against which all should be insulated. Needless to say, intelligent people need to make their way among them and be able to evaluate them. Here again the research spirit is an ever-present and indispensable help.

VII

The changes in science itself, and the uses as well as the misuses of science, necessitate the research spirit if the citizen is to evaluate these changes properly and make the requisite adaptations. Our students, in the future, either as scientists or intelligent laymen, must be ever open-minded, flexible and eager for the best truth and the best new conclusions. The revolutions in thought precipitated by science, such as those connected with the names of Copernicus, Galileo, Newton, Harvey and Darwin, have just begun. We must be prepared to meet new facts in every field of scientific endeavor.

Furthermore, science is becoming so specialized and the amount of scientific knowledge so vast that the average citizen can not possibly know it all nor can he always utilize what he does know in his own life. Therefore each of us must become his own general scientist to some

extent. This is unthinkable without the research spirit.

Certain precautions must be observed in the utilization of science that can only be dictated by the research spirit. The second-rate scientists, and especially the popularizers, promise anything, and lead large numbers of people, now easily conditioned to any reputed scientific findings, to accept almost everything uncritically. Thus mere scientific assumptions become dogma for many, and a new bigotry appears comparable to any other in its power of resistance to truth. Men still need to think.

Science gives us prodigious power. How it is used depends upon the standards and perspective of the individual and the traditions and ideals of the group. The same scientific training equips men for the discovery of an anesthetic as of some poison gas, the production of the most deadly explosives as of the most effective soil fertilizers. The radio is an instrument that may confound and exploit us, or it may give us the sublimest creations of man and enoble us. There is much truth in Thoreau's statement, "Our inventions are improved means to an unimproved end." We are, from many points of view, acquiring control of stupendous forces faster than we are developing the abilities to control ourselves. We are threatened with barbarism. Science can destroy our civilization; on the other hand, it is capable of converting the world into Utopia. Never before have men generally so needed real scientific background, mental poise, social perspective, moral balance and courage and the ability to evaluate and foresee. Never before have they so needed the research spirit.

Many of these college youth will enter professions or specialized technical callings. These too are changing continually. Research in chemistry, physiology, bacteriology and surgery is causing medical science to be in process of con-

tinual change, and the successful doctor must be able to incorporate these new findings and techniques into his own practice if he is properly to fulfil his function. The discovery of new materials, new data and new processes is forcing architecture and engineering to change. New methods and techniques and changing subject-matter are forcing the members of the teaching profession to refurnish themselves everlastingly. The changes in religion and the changing conception of the function of the church are forcing the clergy to readapt themselves. Every department of industry and business is changing in various ways. The individual member of the profession or calling must be alert, flexible in his attitudes, eager for the new truth and method, and he must have the inventiveness and ingenuity to put it into practice.

VIII

Finally there is great confusion to-day regarding the rightness and wrongness of individual acts. The present college generation especially has a difficult problem on its hands. It is seeking system and validity for its conduct. The reasons for the confusion are numerous. There is so much dishonest but temporarily successful behavior. So many of the "best" people are hypocrites; so much business is exploitation; so many statesmen vote dry and drink wet; so much patriotism turns out to be a distortion, and the sacred rights of property are invariably placed before the sacred rights of man. It is no wonder that the prevailing ethical maxim should be, "It's all right if you can get away with it."

At the same time science has taken away the supernatural bases of our morality. It demonstrates, for example, that any given ethical code is only one of a number practiced and maintained with equal success, and that two given

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codes may be diametrically opposed in important aspects. Public opinion, another element in giving ethical codes fixity and sanction, has almost disappeared as far as private behavior is concerned. When it does operate it is weak and confused.

Finally, the social situations over which ethics presides as regulator are changing continually and along fundamental lines. Old rules become inadequate and ethical elements must continually be scrapped lest they become an incubus.

And yet we do have to live together and we must have order. Both present and future generations must make a most rapid, far-reaching and consciously intelligent orientation of ethical ideas to a continually altering social structure. We must be willing to make a careful examination of facts and requirements with respect to social relationships. We need the knowledge, imagination and logic to see and foresee social effects. We must be sane and calm and refuse to come to any but justifiable conclusions. We *must* have the research spirit.

IDEAS OF ORIGIN AMONG THE ANCIENT EGYPTIANS AND BABYLONIANS

By GEORGE J. DUDYCHA

RIPON COLLEGE

It has almost become traditional, when dealing with any phase of thought, to begin with a consideration of Greek ideas. The history of psychology begins with Plato; biologists refer to Aristotle, and sociologists to Plato's "Republic"; the history of Western philosophy almost invariably begins with Thales. Although we may readily admit that the Greeks are our progenitors in thought—our philosophical forefathers—we too often fail to recognize the thought which antedated that of the Greeks. We turn to Thales as though he were the Adam of all thought and neglect the equally profound ideas of the more ancient peoples of Egypt, India, China and Babylonia.

Osborn,¹ Fasten,² the present writer³ and others all have begun with the Greek, Thales, in their accounts of the history of the idea of development. Per-

haps this has led to the misconception that we are unable to trace ideas of origin any farther back than the sixth century B.C., and that the Greeks were the first to speculate concerning the beginning of things. If the thoughtful reader will reflect a moment, he will probably realize that our customary starting-point—Greek thought—is more convenient than logical, and hence he will be anxious to inquire concerning the ideas found in more ancient sources. Although the Greeks made contributions to philosophy of inestimable value, we do not know to what extent their ideas were influenced by those of more ancient peoples. Hence let us take another step into the remote past, beyond the thought of the Greeks, and see what ideas of origin we can find among the ancient Egyptians and Babylonians.

When we turn to the ancient sources of the Egyptian and Babylonian ideas concerning the origin of things we encounter many difficulties. In the first place, the ideas can not be ascribed to particular thinkers, as in the case of the

¹ Osborn, "From the Greeks to Darwin," Scribners, New York, 1929.

² Fasten, "Origin through Evolution," Knopf, New York, 1929.

³ Dudycha, "What is Evolution?" SCIENTIFIC MONTHLY, 29: 317-332, October, 1929.

Greeks, for the tablets and papyri are in many cases unsigned, and if they are signed, the signature is not that of the author of the ideas but of the copyist or of the priest who authorized the copying. Also the sources are for the most part fragmentary and thus complete accounts of the ideas of origin are impossible. Since the texts available to scholars are in many cases corrupt because of the numerous times they have been copied by careless scribes, it is extremely difficult to interpret certain passages and to ascertain the original ideas. Some of the ancient legends date back to the second, third and possibly fourth millennium B.C. Since they had been perpetuated orally through innumerable generations before being recorded, they were developed into a number of versions, which makes interpretation very difficult. In some cases the scribes themselves did not understand the texts which they copied and hence modified them to suit their own fancies by omitting some ideas, by adding others or by combining a number of legends or fragments of legends to form a more or less incoherent story. Fortunately, in spite of these difficulties, tablets and papyri have been unearthed which bear well-preserved records of ancient ideas of origin which apparently date back to the early dynasties of Egypt and to the ancient Sumerians who preceded the Semites in Babylonia. It is to these primeval records that we shall now turn for a knowledge of the early Egyptian and Babylonian ideas of origin.

In the British Museum may be found the remarkable "Legend of the Creation," a well-written papyrus acquired by A. H. Rhind in 1861 or 1862. This papyrus, which was discovered in the famous hiding-place of the royal mummies at Dêr-al-Bahari, bears the date, the "first day of the fourth month of the twelfth year of Pharaoh Alexander, the son of Alexander," or 311 B.C. We

must bear in mind, however, that this Nes-Menu papyrus is not the first account of the legend but a copy, and that scholars feel quite certain that the legend itself dates back to several millennia B.C. Thus the discovery of this papyrus was a particularly fortunate one, for we now have a source which bears ideas of origin which antedate those of the Greeks. Dr. Budge in his first volume of "Egyptian Literature" gives us the legend of the creation in hieroglyphic type and also a page-for-page translation. This Nes-Menu papyrus bears two accounts of the creation which are alike except for some details and for a few additions to the second account which were apparently made by the copyist. The first account of the history of creation is as follows:

THE BOOK OF KNOWING THE EVOLUTIONS OF
RA, AND OF OVERTHROWING APEP

[These are] the words which the god Neb-er-tcher spake after he had come into being: "I am he who came into being in the form of the god Khepera, and I am the creator of that which came into being, that is to say, I am the creator of everything which came into being; now the things which I created, and which came forth out of my mouth after that I had come into being myself were exceedingly many. The sky [or heaven] had not come into being, the earth did not exist, and the children of the earth and the creeping things had not been made at that time. I myself raised them up from out of Nu, from a state of helpless inertness. I found no place whereon I could stand. I worked a charm upon my own heart [or will], I laid the foundation [of things] by Maât, and I made everything which had form. I was [then] one by myself, for I had not emitted from myself the god Shu, and I had not spit out from myself the goddess Tefnut; and there existed no other who could work with me. I laid the foundations [of things] in my own heart, and there came into being multitudes of created things, which came into being from the created things which were born from the created things which arose from what they brought forth. I had union with my closed hand, and

⁴ Budge, "Egyptian Literature," Vol. I. "Legends of the Gods," London: Kegan Paul, Trench, Trubner and Co. Ltd., 1912.

I embraced my shadow as a wife, and I poured seed into my own mouth, and I sent forth from myself issue in the form of the gods Shu and Tefnut. Saith my father Nu: My Eye was covered up behind them [i.e., Shu and Tefnut], but after two *hen* periods had passed from the time when they departed from me, from being one god I became three gods, and I came into being in the earth. Then Shu and Tefnut rejoiced from out of the inert watery mass wherein they were, and they brought to me my Eye [i.e., the Sun]. Now after these things I gathered together my members, and I wept over them, and men and women sprang into being from the tears which came forth from my Eye. And when my Eye came to me, and found that I had made another [Eye] in place where it was [i.e., the Moon], it was wroth with [or raged at] me, whereupon I endowed it [i.e., the second Eye] with [some of] the splendor which I had made for the first [Eye], and I made it to occupy its place in my Face, and henceforth it ruled throughout all this earth. When there fell on them their moment through plant-like clouds, I restored what had been taken away from them, and I appeared from out of the plant-like clouds. I created creeping things of every kind, and every thing which came into being from them. Shu and Tefnut brought forth [Seb and] Nut; and Seb and Nut brought forth Osiris and Heru-khent-anmaati and Set and Isis and Nephthys at one birth, one after the other, and they produced their multitudinous offspring in this earth."⁵

We are not told in this account of the creation where and how Neb-er-teher came into being; but, as Budge says, "It seems as if he was believed to have been an almighty and invisible power which filled all space." This immediately suggests Anaximander's idea of "the boundless" as the source of all things. Although the Egyptians labeled this source-of-all-things and called it a god, their fundamental idea, that there is an indefinable boundless something from which all things issue, is certainly much like that of Anaximander. Another idea which we find expressed here and which was emphasized by the early Greeks is that of the unity of the primal principle. Neb-er-teher, who took on the form of Khepera, the creator god of the

Egyptians, was the sole primal source of all creation.

The next significant idea we find embodied in the statement, "I myself raised them up from out of Nu, from a state of helpless inertness." Nu, sometimes referred to as Nun, was the great watery abyss, the primal watery mass which was the source and origin of all things organic and inorganic. "The most wide-spread of all," says Steindorff, "was a belief which perhaps proceeded from the priestly college of Heliopolis. According to this there was in the beginning a great primordial body of water called Nun, which contained all male and female germs of life. Out of it came the sun, the Rē, as it is called in Egyptian. In this water, too, lay the earth-god Geb and the heavenly goddess, Nut, locked in a close embrace, until the god of the air, Show, parted them from one another and carried the goddess of heaven in his arms into the upper regions."⁶ This concept of Nu, the great abyss, symbolized by the ocean, a representative of which was the gentle Nile, is a most interesting concept which contains two fundamental ideas. First the idea of water as the primeval substance. This idea we encounter among the Greeks. Thales, the Ionian, named water as that from which all things come, and Aristotle iterated the idea with reference to all life. Also we note that in Nu all things were in "a state of helpless inertness" from which they were freed by becoming actual. Of course, we must beware of too free speculation concerning the ideas of the ancient Egyptians, but we can not avoid a reference to Augustine in this connection. For Augustine all things were potential in an original germ or seed from which all things came. It is this potentiality of forms in the primordial

⁵ Budge, "Legends of the Gods," Vol. I, pp. 3-7.

⁶ Steindorff, "The Religion of the Ancient Egyptians," p. 36, G. P. Putnam's Sons, New York, 1905.

mass which seems to be common to both concepts.

In a cosmogonic fragment from the "Book of the Dead," we find another reference to Nu.

Furthermore I shall ruin all that I have made.
This earth will appear [?] as an abyss,
In [or as] a flood as in its primeval condition.
I am the one remaining from it together with
Osiris.

My forming is [then] made to me among other
[?] serpents

Which men never knew,
Which the gods never saw.⁷

Here another aspect of Nu is emphasized. Not only is Nu the source of all things, but the end as well—that from which all things come and that to which all things return. Here, again, is Anaximander's idea.

Again we read in our text, "I laid the foundation [of things] by Maät." The goddess Maät, who assisted Khepera in the process of creation, is usually regarded as the goddess of law, order and truth. Budge is inclined to believe that in this particular instance she plays the part of Wisdom. Thus, in the thought of the Egyptians, we again find a concept which has been fundamental to all concepts of origin and development, namely, the concept of law and order.

The first products of creation, the legend tells us, were Shu, the god of air and dryness; Tefnut, the goddess of liquids or the waters above the heavens; Keb, the earth-god, and Nut, the sky-goddess. Thus first air and clouds appeared which separated the heavens from the earth. Later the legend speaks of Neb-er-tcher's or Khepera's eye or the sun as having some calamity which extinguished its light. "This calamity," Budge says, "may have been simply the coming of night, or eclipses, or storms; but in any case the god made a second Eye, i.e., the Moon, to which he

gave some of the splendour of the other Eye, i.e., the Sun, and he gave it a place in his face, and henceforth it ruled throughout the earth, and had special powers in respect of the production of trees, plants, vegetables, herbs, etc."⁸ The latter part of the legend is somewhat confusing, especially with regard to the creation of man, with which we shall deal presently.

In the Trismegistic "Traetates" the tradition and wisdom of ancient Egypt has come down to us in a slightly modified Alexandrian form. Although this source has been assigned to the fifth or possibly sixth century B.C., the ideas "go back in an unbroken tradition of type and form and context to the earliest Ptolemaic times." Most of this Hermetic or Trismegistic literature has been destroyed, but among that which has not perished we find "The Vision of Hermes,"⁹ under the name of Poimandres, which is in the beginning of the books of Hermes Trismegistus. "The Vision of Hermes" is the revelation of the origin of things by Osiris who in later Egyptian thought became associated with Nu, the primal mass. Hermes' first request of Osiris was "to behold the source of beings." Immediately he found himself in a chaos filled with smoke. Then a voice, *the cry of light*, rose from the great abyss and a flame darted to the ethereal heights. Hermes ascended with the flame and observed order appear, and that *the voice of light* filled infinity. Hermes did not understand the meaning of all he saw and hence Osiris explains:

Thou wilt now learn. Thou hast just seen what exists from all eternity. The light thou didst first see is the divine intelligence *which contains all things in potentiality*,¹⁰ enclosing the models of all beings. The darkness in

⁸ Budge, *loc. cit.*, p. xxi.

⁹ Hermes was the name given by the Greeks to the Egyptian god Thoth or Tehuti, the god of wisdom, learning and literature.

¹⁰ Italics are mine.

⁷ Gray (Editor), "The Mythology of all Races," Vol. XII, Muller, "Egyptian," p. 72, Marshall Jones Company, Boston, 1918.

which thou afterwards plunged is the material world on which the men of earth live. But the fire thou didst behold shooting forth from the depths, is the divine Word.¹¹

But Hermes desired more knowledge. "Since things are so," said Hermes, "grant that I may see the light of the world; the path of souls from which man comes and to which he returns." Thus Hermes found himself in the center of the seven spheres which stretched above him, tier upon tier, like seven transparent concentric globes. Again the great Osiris speaks:

"Look, listen, and understand. Thou seest the seven spheres of all life. Through them is accomplished the fall and ascent of souls. The seven genii are the seven rays of the world-light. Each of them commands one sphere of the spirit, one phase of the life of souls. . . .

"Dost thou see," said Osiris, "a luminous seed fall from the regions of the milky way into the seventh sphere? These are germs of souls. They live like faint vapors in the region of Saturn, gay and free from care, knowing not their own happiness. On falling from sphere to sphere, however, they put on increasingly heavier envelopes. In each incarnation they acquire a new corporeal sense, in harmony with the surroundings in which they are living. Their vital energy increases, but in proportion as they enter into denser bodies they lose the memory of their celestial origin. Thus is effected the fall of souls which come from the divine ether. Ever more and more captivated by matter and intoxicated by life, they fling themselves like a rain of fire, with quiverings of voluptuous delight, through the regions of grief, love, and death, right into their earthly prison where thou thyself lamentest, held down by the fiery center of the earth, and an empty dream. . . . Do you see this swarm of souls trying to mount once more to the lunar regions? Some are beaten back to earth like eddies of birds beneath the might of the tempest. The rest with mighty wings reach the upper sphere, which draws them with it as it rotates. Once they have come to this sphere, they recover their vision of divine things. This time, however, they are not content to reflect them in the dream of a powerless happiness; they become impregnated thereby with the lucidity of a grief-enlightened consciousness,

¹¹ Brown, "The Wisdom of the Egyptians," p. 264, Brentano's, New York, 1923.

the energy of a will acquired through struggle and strife. They become luminous, for they possess the divine in themselves and radiate it in their acts."¹²

In "The Vision of Hermes" there are at least two thoughts which we must note, first, the potentiality of all things in divine intelligence, and second, the descent of the souls through seven stages. Here we note, then, an evolutionary—unfolding—process, and an epigenetic—building-up—process. The two processes, however, are not incompatible, for the souls, although passing through an epigenetic process towards materiality, are the unfoldment of that which is in divine intelligence. "One only soul, the great soul of the All, by dividing itself out, has given birth to all the souls that struggle throughout the universe." Thus, here again, we have the ideas of unity of origin and process of development expressed.

The descent of the souls, told in "The Vision of Hermes," is one account of the creation of man. In the "Legend of the Creation" we found two other and somewhat incompatible ideas of the origin of man. The first was that Neb-er-teher wept, "and men and women sprang into being from the tears which came forth from my eye." In the other version, the gods gave birth and "produced their multitudinous offspring in this earth." According to the second notion, men are mortal gods. This lack of harmony which we find with regard to the origin of man is probably due to the fact that these conflicting legends appealed to the scribes who desired to perpetuate them in spite of their lack of unity. Then again, it has been observed that the very lack of unity in the "Legend of the Creation" made it a more potent charm against Apep and his fiends.

Now that we have an idea of the Egyptian notions of origin, let us turn

¹² Brown, *loc. cit.*, pp. 266, 267-8, 269.

to the ancient Sumerians and the Semitic Babylonians who succeeded them. At Nippur, tablets, inscribed at the close of the third millennium B.C., have been found which bear Sumerian and Semitic accounts of creation. Although the available text was inscribed before 2100 B.C., the original composition dates back to a much earlier time, and thus we are again able to examine ancient ideas of origin.

It is interesting to note that the ancient Sumerians, as the Egyptians, Hebrews and Greeks, assumed that water is the source of all things. King renders a fragment of a poem which deals with creation as follows:

When the height heaven was not named,
And the earth beneath did not bear a name,
And the primaeval Apsû who begat them,¹³
And Mummu, and Tiamat who bore them¹³
all—

Their waters were mingled together,

Then were created the gods in the midst of
[their waters],
Lakhamu and Lakhamu were called into
being. . . .¹⁴

He goes on to say that the text gives two actual causes of creation, the one an impersonal cause and the other the action of a god. In the following extract we note that before creation all the world was a sea. Here, however, the primeval water is not personified and hence the impersonal source of all things.

No city had been created, no creature had been
made,
Nippur had not been created, Ekur had not
been built,
Erech had not been created, Eanna had not
been built,
Apsû had not been created, Eridu had not been
built,
Of the holy house, the house of the gods, the
habitation had not been created.
All lands were sea.

¹³ *I.e.*, the gods.

¹⁴ King, "Legends of Babylon and Egypt in Relation to Hebrew Tradition," p. 122, London, 1918.

At the time when a channel [was formed] in
the midst of the sea,
Then was Eridu created, Esagila was built,
etc.¹⁵

A different picture of beginnings is given in another Sumerian myth which was discovered on a tablet from Nippur. Although in this myth water is considered as the source of all life, the existence of land is presupposed—land which is bare and desolate. King says: "The underlying idea is suggestive of a period when some progress in systematic irrigation had already been made, and the filling of the dry canals and subsequent irrigation of the parched ground by the rising flood of Enki was not dreaded but eagerly desired."¹⁶ Here we have an analogy. As water revives vegetation, so water must have been essential or the cause of the first appearance of life.

As the Egyptians regarded the Nile as a representative of Nu, so the Babylonians attributed creative powers to the Euphrates. This is indicated by the following lines from a Semitic incantation:

O thou River, who didst create all things,
When the great gods dug thee out,
They set prosperity upon thy banks.
Within thee Ea, King of the Deep, created his
dwelling.

The Flood they sent not before thou wert!¹⁷

Yet another idea is to be noted in the Semitic-Babylonian version of the creation of the world. Creation for the Semites was the result of a conflict in which order emerged out of chaos because of the personal triumph of the creator. This dualism does not seem to be present in the more primitive Sumerian ideas. This idea of conflict we have encountered before. Empedocles posited two world forces, love and hate, which were in conflict, and the triumph of love over hate was the cause of organic evolution.

¹⁵ King, *loc. cit.*, p. 124.

¹⁶ King, *loc. cit.*, p. 125.

¹⁷ King, *loc. cit.*, p. 128.

Since we have examined in detail the ideas of origin found among the ancient Egyptians and Babylonians, let us now briefly survey the main ideas which we found. Although the references to the creation are by no means numerous in Egyptian literature, because the Egyptians' interest, which almost amounted to an obsession, was in a future life rather than in the past, we fortunately have the invaluable Nes-Menu papyrus—the "Legend of the Creation." In spite of the fact that this ancient legend was appropriated to Egyptian theology by the priests, we have found in it fundamental ideas which are common to other cosmogonic views. Especially did we note striking likenesses to Greek thought.

Neb-er-teher, the invisible power which filled all space and which was the primal source of all creation, suggests at once "the boundless" of Anaximander and the monisms urged by a whole host of thinkers. Nu, the great watery abyss, again suggests the Greeks who early perceived how indispensable is water to life. But Nu has a further significance: in it all things are potential and to it all things return. These ideas were expressed by Augustine and by Anaxi-

mander. As in Western thought, law and order played a part in the Egyptian idea of creation. In "The Vision of Hermes," we noted a number of significant ideas: the cry of light was symbolized as a flame—the primacy of fire; the potentiality of all things in divine intelligence; the definite epigenetic process through which the souls pass on their way towards materiality.

When we turned to the Sumites and Semites we found that they too recognized water as the primal source of all creation. In the Sumite cosmogonic idea, the sea is an impersonal force not personified as by the Egyptians. The idea of conflict and subsequent triumph of the creator, which reminds us of Empedocles, is an idea not found among the Sumerians but apparently originated by the Semitic-Babylonians.

Thus in closing we must reiterate. The Greeks were not the first to speculate concerning the origin of things, for we find among the Egyptians and Babylonians cosmogonic ideas of far more ancient origin, which, when divested of their theological implications and deity names, are not so far different in nature and significance from those of more recent and of Western thought.

SCIENCE SERVICE RADIO TALKS

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COLD LIGHT

By Dr. E. NEWTON HARVEY

PROFESSOR OF PHYSIOLOGY, PRINCETON UNIVERSITY

THE words "cold light" seem at first sight to state a paradox. So closely associated are light and heat in all our experience that the two would seem inseparable. The sun is not only the brightest but also the hottest object in our immediate neighborhood.

Practically every illuminant in use to-day is patterned after the sun and stars. The attempt is made to heat an incandescent filament to the highest temperature possible. We can not attain the temperature of the sun, five or six thousand degrees, but we do attain two fifths the temperature of the sun and a brightness sufficient to convert our principal thoroughfares into great white ways. No artificial lamp is known but that gives off ample heat to be felt by the hand. It is all "hot light." The heat is not only a drawback; it is an actual waste, a waste so great that it represents about 98 per cent. of the total energy. We use a 50 horse-power engine to run the dynamo that lights a few bulbs, when 1 horse-power might do the same thing if we knew the secret of the process. Modern incandescent bulbs are already many times more efficient than those first constructed, but we are apparently approaching the limit. How can we improve the efficiency of our light-producing processes still further? I think we must turn to a type of light which, as we say, radiates very selectively, *i.e.*, it gives off mostly radiant wave-lengths which affect our eye and very few of those which have great heating power but which are invisible. Such

lights we speak of as cold lights or luminescences, and contrast them with hot lights or incandescences.

Luminescences are by no means unusual. They are in fact quite common. Two lumps of sugar rubbed together in a perfectly dark room will give off a faint light. We call it tribo-luminescence. Tire tape or surgeon's tape gives a greenish glow when stripped from the roll. Common salt can be made to luminesce when it crystallizes rapidly. These lights are very faint, and indeed that is characteristic of luminescence in general, but it is not always a serious drawback for practical purposes. The radium paint used on watch dials is a luminescence, a radio-luminescence, and yet has a very useful rôle to play. In fact the modern trend in lighting is that of indirect illumination. A very bright light is fatiguing, indeed obnoxious. We spread our bright light over a large area by shades or reflectors and thus avoid the glare, reducing what is called the "intrinsic brilliancy" of the light. Some luminescences are bright enough for practical illumination but the color is bad. I refer to neon lamps, so widely used as signs and in advertising. They are true luminescences and among the most efficient types of commercial lamps but they still leave a great deal to be desired as a general illuminant.

Perhaps the most promising field for study is that of chemi-luminescences, the luminescences which accompany chemical reactions. These appear dur-

ing chemical change, chiefly during oxidation, and can be studied in test-tubes. A number of organic compounds in water solution can be made to produce quite a bright light with only a few thousandths of a degree rise in temperature. This is the method of producing light adopted by the firefly and other luminous animals. The layman does not realize how many creatures have this power. Many of them live in the depths of the sea or under rocks and stones. Some microscopic forms develop under favorable conditions at the surface of the sea in enormous numbers, giving rise to the phosphorescence, so well known to ocean voyagers. Others develop in decaying wood, producing the fox-fire of forests. Even some bacteria are luminous, causing the glow of dead fish or meat in refrigerators.

All emit a light which is a luminescence, a bio-luminescence, and which results from the oxidation of a compound manufactured in their tissues and called luciferin. Its exact composition is not known but we have considerable knowledge about it, and I believe the synthesis of luciferin is merely a matter of time. Let us inquire somewhat more closely into the luminescence of this compound and the light of living things in general.

It should be clearly understood at the start that animal light—cold light—is no different in its physical make-up from any other kind of light. Animal light can be reflected and refracted and polarized, will affect a photographic plate, and is stopped by materials capable of stopping similar wave-lengths from any other source. Such a light would do perfectly well as a practical illuminant. The light of some luminous animals has an intrinsic brilliancy sufficiently high for general illumination. It has been calculated that an area of firefly light 6 feet in diameter on the ceiling of a room 9 feet high would give ample illumina-

tion for reading or drawing on a table 3 feet high.

Not all luminous animals are as bright as the firefly. Many produce only a diffuse glow from irregular areas or from the whole surface of the body, and some pour out a luminous substance leaving a trail of light behind them as they swim, while others have the light-producing cells concentrated into a definite organ. In some cases this light organ is provided with reflectors for directing and a lens for concentrating the beam, as well as opaque screens to protect the tissues of the animal from its own light and a mechanism for turning the light off and on. In a few forms are color screens for regulating the quality of the light. A veritable lantern is formed which we may suppose to be of some important use to its possessor.

What goes on in the cells of those animals which can produce light? They are the test-tubes of the living organism. I have said that a compound, luciferin, is oxidized or burned, a process similar to that which takes place in a burning candle. This oxidation occurs in the presence of another compound, luciferase, an enzyme or catalyst. In this respect it differs from a burning candle. Now a catalyst is a substance which takes no permanent part in a chemical reaction, but by its mere presence causes the reaction to proceed. It has been called a "good mixer" or a "chemical parson," because it causes substances to become acquainted and unite. Its effect has been compared to that of oil on a rusty machine, and catalysts are becoming of more and more importance in the chemical industries.

During the oxidation of luciferin, the luciferase molecules pick up some of the energy of oxidation and are "excited," as we say, to emit light, when they return to their normal condition. They are then ready to repeat the cycle again.

All this happens in a time interval measured in fractions of a millionth of a second. The average of all the minute amounts of light emitted by all the luciferase molecules give us the firefly's light as it appears to our eye.

There still remains the question of what happens to the luciferin after it has been oxidized or burned. For many years those who thought at all about luminous animals supposed that the luciferin oxidized with formation of carbon dioxide and water, the same products as appear when a candle burns. This is not the case, and in this fact lies the secret of the small energy change occurring during its oxidation. Luciferin does not oxidize to CO_2 and H_2O , but to a substance I have called oxy-luciferin.

The important point is that by simple methods oxyluciferin can be easily reduced to luciferin. Reduction is the opposite of oxidation. The reformed luciferin can be again oxidized with luminescence. Not only is the luciferase able to pick up energy from oxidizing luciferin again and again but the luciferin is capable of alternate oxidation and reduction in a continuous cycle. Why not allow the two processes to proceed side by side in the same vessel and obtain a continuous light? Reduce the luciferin as fast as it is oxidized, and use it over and over again.

This would be comparable to burning a candle, and then by some means recombining the oxidation products of the candle, the water and carbon dioxide, to tallow again. Our present way to reform a tallow candle is to let sunlight fall upon the leaves of the green plants, when CO_2 and H_2O will be recombined with absorption of the energy of sunlight, and starch, a compound rich in energy, will be built up. Then some

animal must eat the starchy food and convert it into tallow, which is again in a position to be burned with liberation of energy, some of which goes into the light of the candle.

What is impossible in the case of the tallow is quite possible in the case of luciferin. By simultaneous reduction of oxyluciferin and oxidation of luciferin, a continuous light can be produced—not a very bright light, to be sure, but one which demonstrates the principle, and the principle is the important thing.

And what an economical process this is! Here you have an animal that makes its fuel and burns it and produces light, practically pure visible light, for it is not contaminated with those unbidden rays we can not see; and then it takes the combustion product and reconverts it into fuel again, and the fuel is ready to be burned a second time. The firefly is able to unburn its candle. And all this by a process which is in no sense a mystery. The chemist calls it a reversible reaction, and if you should ask him whether this is not a rather rare thing, he would probably reply: "All chemical reactions are reversible, but to a different degree."

The application of an old principle in a new way has solved many a problem. It is perhaps too soon to predict what may be the commercial future of cold light, but it is worthy of emphasis that such a development would be a very decided step in the right direction. We usually find that nature has selected efficient and economical ways of doing things and it is no wonder that the cold light of animals has been the goal of the illuminating engineer, ever since our advancing knowledge reached the point where appreciation of the principles of light-production was possible.

SUN-SPOTS AND RADIO

By Dr. H. T. STETSON

DIRECTOR OF THE PERKINS OBSERVATORY, OHIO WESLEYAN UNIVERSITY

SOME radio enthusiasts who have been long at the game may sense that of late years long distance reception has not been coming in as it did in the early days of broadcasting, five or six years ago. This is the more significant when we consider that the output of the broadcasting stations has been increased immensely and that great improvement has been made in receiving sets over this interval.

Studies during the last few years indicate that there are cosmic causes at work which may profoundly influence the electrical state of our atmosphere which these radio waves traverse. Probably the sun is the one astronomical body most responsible for changes in our terrestrial affairs. Every radio fan knows that day-time reception is vastly poorer than night-time reception in the broadcasting zone. Here is the most obvious exhibition of the effect of the sun's rays upon radio. On the other hand, both day and night reception vary greatly from time to time for what has often seemed to be no good reason at all. It is from relatively very recent researches that we have come to believe much of the cause for this varying degree of reception is to be found in the sun's atmosphere itself.

When we examine the sun's surface through the telescope, we find that it presents a strange mottled or granular appearance. In this mottled surface there develop now and then dark patches, often growing into huge black areas surrounded by a somewhat shaded region called the penumbra. These dark areas are the sun-spots. Whatever may be ultimately accepted as the best explanation of the spots, one can not go far wrong in picturing a sun-spot

as a terrific storm in the sun's atmosphere, a cyclonic whirlwind for which the most violent tropical hurricane would be a microscopic illustration.

One of the most extraordinary features of sun-spots is the periodicity with which they appear on the solar surface. For nearly a century and a half sufficiently accurate records of the appearance of sun-spots have been made, so that if we plot the degree of spottedness of the solar surface year by year, we discover a periodic rise and fall in the stormy condition of the sun's surface spanning approximately eleven years. We are now not far from what we call a sun-spot maximum. About six years ago sun-spots were very scarce and, when they occasionally appeared, were very small and insignificant affairs.

Curiously enough, at the beginning of a sun-spot cycle the spots appear on the sun's surface at relatively high latitudes, and as the cycle progresses they increase in size and number and break out at successively lower latitudes on the solar sphere, a given cycle of spots finally disappearing just a few degrees from the solar equator.

The true character of sun-spots as magnetic whirls in the solar atmosphere was first established by Hale, of the Mount Wilson Observatory, in 1908. By a special adaptation of the spectroscope, Hale was able to photograph different layers in the solar atmosphere and establish the existence of vortices similar to the whirlwinds which are characteristic of cyclonic storms in the earth's atmosphere. Furthermore, by analyzing the character of the rays of light radiating from the sun-spots, Hale was able to demonstrate that the character of the light emitted from the center of these

gigantic whirls betrayed unmistakably that they were the poles of powerful electromagnets, and that the doubling and tripling of lines in the spectrum in the vicinity of sun-spots was due to the magnetic effect announced by Zeeman in 1896.

The mention of sun-spots invariably raises the question of a possible connection between the spots on the sun and terrestrial phenomena. Some statisticians with an insatiable appetite for correlations have attempted to connect with sun-spots almost every cycle in world affairs from fluctuations in the New York stock market to the fecundity of rabbits in northern Canada. In the popular mind, almost every world catastrophe has sooner or later been attributed to sun-spots, from a Florida hurricane to the great world war, both of which, by the way, did culminate around a sun-spot maximum.

But seriously there are to the scientist certain well-recognized phenomena on the earth which pass through cycles whose correlation with the sun-spot cycle is unmistakable.

For more than a century and a half records of the numbers of sun-spots have been kept and afford data for a study of their periodicity over a range of about fifteen eleven-year cycles. For more than a century records of the variation in the earth's magnetism have been made and preserved. The remarkable correlation of sun-spots with magnetic changes on the earth is at once apparent when we make a graph of the number of sun-spots and compare this with a similar graph for changes of the compass needle. Simultaneously with the so-called magnetic storms, which are wont to sweep the earth upon the appearance of great sun-spot activity, we witness frequent and brilliant displays of the aurora borealis.

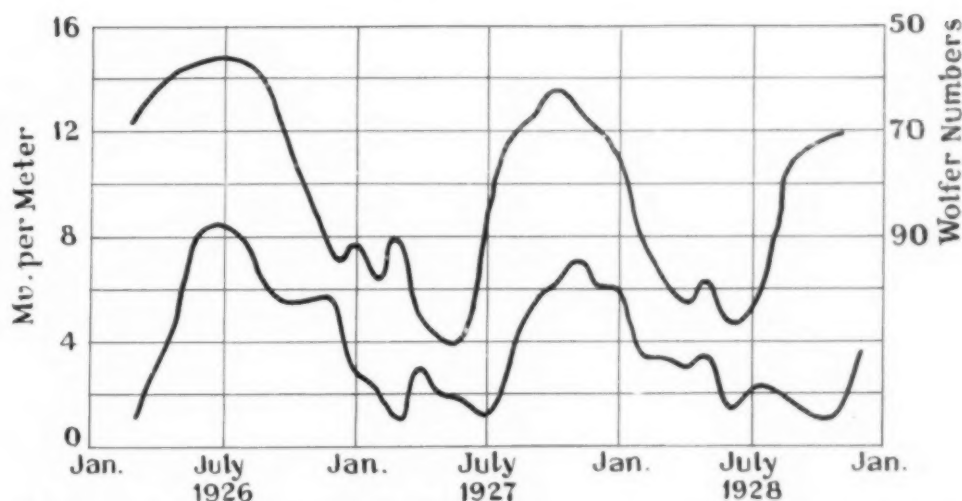
The auroral light is due to an electronic discharge in the upper and highly rarefied atmosphere of the earth, and is

most probably activated by charged particles of electricity emanating from the sun whose activity varies with the sun-spot cycle. It seems probable that the magnetic vortical whirl of a sun-spot acts as a directing field in guiding electrons escaping from the sun. When a conspicuous spot appears near the center of the solar disk, and is therefore approximately in line with the earth and the sun's center, there is a particularly good chance of the ejected electrons striking the earth's atmosphere and causing an ionization or electrification of the upper atmosphere giving rise to an auroral display. At the same time the induced earth currents will distort the earth's magnetic field, causing the small variations in the compass needle so characteristic of a "magnetic storm."

While for many generations scientists have recognized the recurrent cycle in solar activity and the magnetic changes in the earth, never before the present period of sun-spot activity has it been possible to study so thoroughly the changing degree of electrification in the earth's atmosphere with the coming and going of the spots across the solar disk. All this has come about by the development of the radio.

The same electric disturbances which alter the earth's magnetic field and produce the displays of the aurorae or northern lights so change the electrical state of our atmosphere that the radio waves are also affected to a very marked degree by the coming and going of the gigantic solar cyclones.

I have before me a graph showing the number of sun-spots during the twelve months of the year 1926, and alongside another graph showing the average condition of radio reception over the North Atlantic, South Atlantic and across the continent. The sun-spot graph is made from the so-called Wolfer numbers. These numbers are based upon the number of spots visible on the sun's surface at a given time and to some extent upon



UPPER CURVE SHOWS INVERTED SUN-SPOT NUMBERS. LOWER CURVE RADIO INTENSITY MEASUREMENTS.

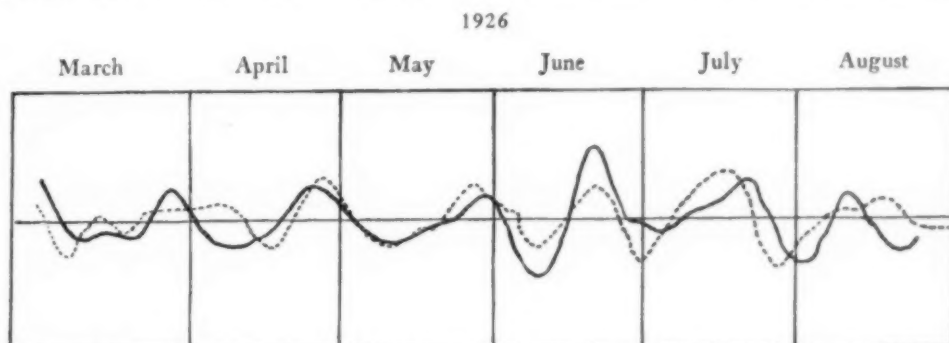
their area, but do not take into account the position of the spot on the sun's disk. The general run of these graphs indicates that radio reception is distinctly impaired by an increase in the sun-spot numbers.

Quantitative measurements of radio reception since 1926 seem to have established beyond much doubt that long distance night reception in the broadcast zone is in general poor when sun-spots are numerous and good when the spots are few. The quantitative measurement of radio reception in the broadcast zone was begun by Mr. G. W. Pickard in his private laboratory at Newton Center in

February, 1926, and great credit is due him for his pioneer work and his pre-eminent contributions in this field.

If we plot a graph of the inverted curve of sun-spot numbers for the years 1926 to 1929, and another graph alongside showing the varying intensity in the carrier wave from WBBM in Chicago as received in Boston and based on the results of measurements by Pickard and Stetson, the inverse correspondence between radio intensities and sun-spot numbers becomes readily apparent.

Every night, Sundays and holidays included, three stations, one in Massachusetts, one in Ohio and one in Cali-



CURVE SHOWING CORRELATION OF SUN-SPOTS WITH RADIO RECEPTION
DOTTED CURVE, THE INVERSE OF SUN-SPOT NUMBERS; FULL CURVE, RELATIVE INTENSITY OF RADIO RECEPTION ON TRANSATLANTIC, SOUTH AMERICAN AND CONTINENTAL RECEPTION.

fornia, tune in on a prescribed wavelength to study the effect of the day's solar radiation upon the electrical state of the earth's atmosphere. Not trusting to any personal impressions as to whether reception is excellent, good, fair or poor, an attendant closes the key to the automatic recorder, whose faithful pen with an impersonal but almost uncanny intelligence writes a continuous record of the intensity of the incoming waves. It is with utter disregard for astronomical or electrical theories that it leaves its unprejudiced and indelible record of what happens for the scientist to analyze.

In addition to the measurement of radio reception the sun is photographed at the Perkins Observatory every clear day in cooperation with the Yerkes, Mount Wilson, Harvard and Naval Observatories, and a careful study made of the size, numbers and location of the sun-spots. It is believed from a preliminary study that the distance of the spots from the center of the disk, or the sun-earth line, is an important factor in the study of correlation of sun-spots with radio reception and other electromagnetic phenomena on the earth.

The radio apparatus recently installed and now in daily operation at the Perkins Observatory is a super-heterodyne receiver especially constructed for the purpose and feeding into a self-recording galvanometer which registers in micro-volts in the antenna the strength of the carrier wave received from the broadcasting station of WBBM Chicago. The apparatus is so designed that the modulations of the carrier wave do not affect the record appreciably, and the results obtained are independent of the nature of the program broadcasted. Realizing the importance of the investigation, the broadcasting station scrupulously maintains a constant energy output in its antenna current, and each night before the observers begin work the receiving set is carefully calibrated

by means of a small sending station in the laboratory placed in close proximity to the receiving set. The output of the local oscillator necessary to maintain full deflection upon the recorder in the receiving circuit is then read from the microammeter in the circuit. The constant of the apparatus for the evening is thus determined. In this way local sources of error both at the broadcasting and receiving ends are eliminated and the resulting measures of the variable reception from night to night may be attributed to the changing electrical conditions of the atmosphere through which the broadcasted wave travels *en route* from Chicago to the receiving station.

Opinions differ as to just what happens when a broadcasted wave travels over the earth. Some believe that an ether wave is propagated which is reflected back to earth from an ionized layer of the earth's atmosphere known as the Kennelly-Heaviside layer which lies some seventy kilometers above the earth's surface. Others maintain that the electric wave is refracted rather than reflected from such a layer. Whatever the mechanism, the wave appears to be turned back by this ionized layer of the earth's atmosphere. Any change in the intensity or degree of this ionization or electrification of the earth's upper atmosphere would have the effect of bending the ray more abruptly or less abruptly towards the earth and thereupon at once be noticed in the intensity of radio reception. The more rapid changes of this sort are doubtless responsible for the phenomena of fading, with which every radio fan is thoroughly familiar. According to our theory the sun constantly bombards the earth's atmosphere with electrons or bundles of energy of high frequency which in turn tear apart the positive and negative charges of the atmospheric molecules, in other words, ionize it to a very consid-

erable extent, thus producing the Kennelly-Heaviside layer. If the sun is more active on occasion, as when large spots appear on its surface, the degree of ionization increases, producing substantially the effect of lowering the Kennelly-Heaviside layer and upsetting the radio reception. When the sun is again less active, the atmosphere tends to return to its normal state of ionization and the radio broadcasting reception tends to improve as the ionized layer lifts.

Further study of the data shows a definite fourteen- or fifteen-month period in solar activity to be exhibited both in the matter of sun-spots and in radio reception.

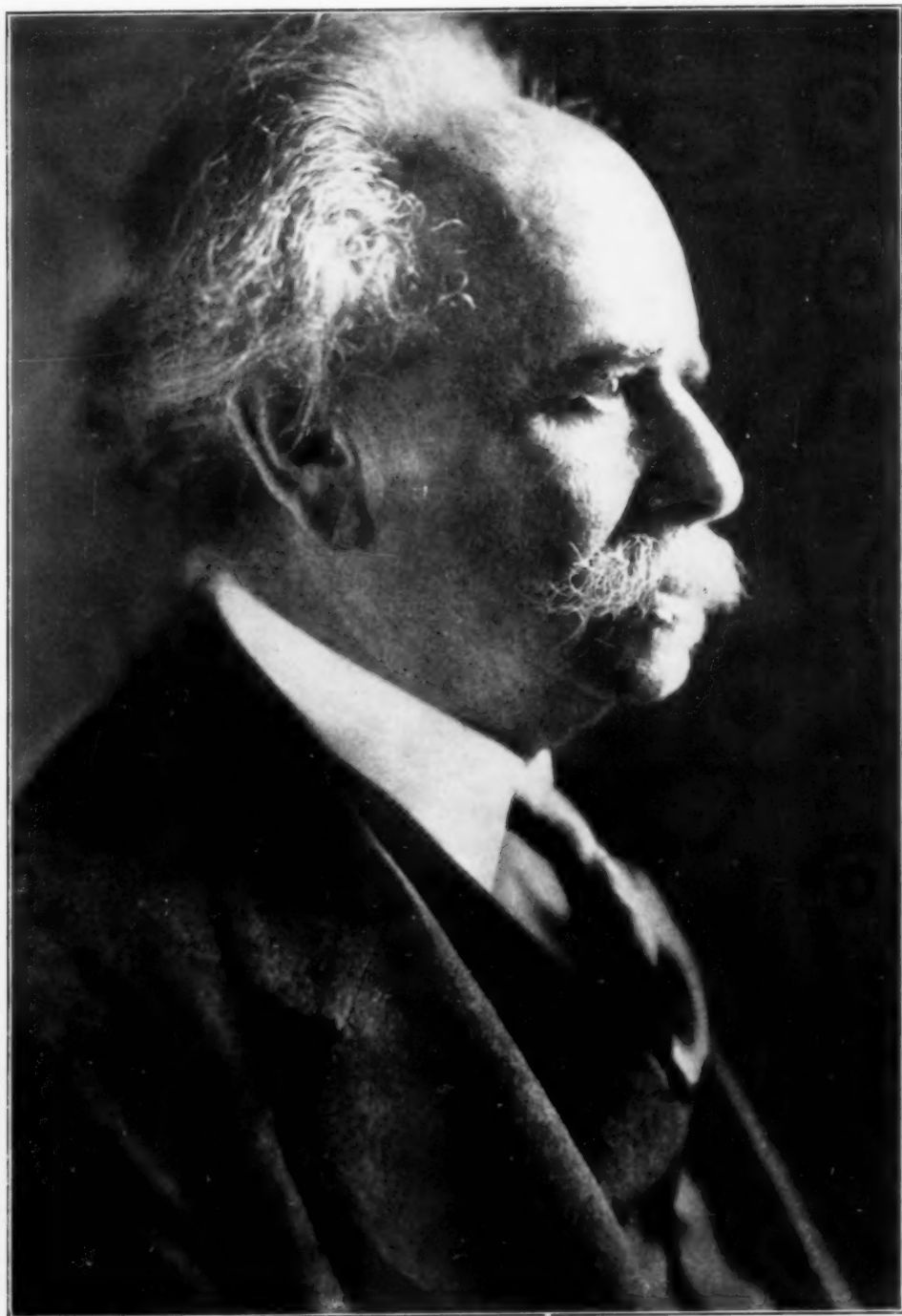
Another important result of the study of the reception curve is to show how completely unfounded is the popular impression that radio reception is universally poor in summer and good in winter. Generally speaking, reception should be better in the winter months on account of the shortened days and decreased daylight. On the other hand, the sun-spots and radio curves of 1926-28 show that the increased solar activity actually gave much poorer reception in the winter months of both 1926 and 1927 than during the summer months of the same years. Conditions again improved in 1928, but reception again became poor in the fall and winter of 1929. It may be mentioned that the high degree of static due to thunder-storms in the summer months results in the fact that the average radio listener will decrease the sensitivity of his set in summer to lessen these disturbances with the necessary accompaniment of low audible intensity of distant stations. Hence the general impression of a low intensity accompanying warm weather temperature.

The rise in sun-spot numbers in the fall of 1929 corroborated to a remarkable degree the evidence I ventured at the New York meeting of the American

Association for the Advancement of Science in 1928, that the period of maximum for the present eleven-year cycle had not been passed. Forecasting on the basis of the fifteen-month cycle, which had worked so effectively during the last few years, the year 1930 should show a general decrease in sun-spot numbers as the year waxes, with a corresponding increase in radio signal strength in the broadcast zone. By the very end of 1930 and the beginning of 1931, the general rise of a secondary sun-spot maximum may be evident. By 1931, however, it is believed we shall be so far from the maximum of the eleven-year period that the secondary maximum period will have no such marked effect upon radio reception and allied electromagnetic phenomena as have the sun-spot maxima of 1928-29. The general lifting of the ionization level in the earth's atmosphere may be expected to continue with fluctuations through the next six years, but in 1934 solar activity should be as quiescent as at the last minimum in 1923.

Perhaps the most remarkable result of our correlation study has been the discovery that radio apparatus has become an effective tool in the study of solar radiation. Furthermore, since meteorological changes are correlatable with changes in radio reception, it is but fair to specify that a new method has been evolved which may ultimately lead to important correlation between sun-spots and the weather. To this end researches will be continued in these closely related lines at the Perkins Observatory.

In conclusion, it may be said that investigations in radio transmission, together with researches in the change in the earth's magnetism and electricity and the ultra-violet radiation of the sun, may yet prove to furnish the most definite data as to changes in solar activity itself.



PROFESSOR FRANZ BOAS

THE PROGRESS OF SCIENCE

PROFESSOR FRANZ BOAS, PRESIDENT OF THE AMERICAN ASSOCIATION
FOR THE ADVANCEMENT OF SCIENCE

FRANZ BOAS, president of the American Association for the Advancement of Science for 1931, was born in Minden, Westphalia, in 1858. He was educated at the universities of Heidelberg, Bonn and Kiel, receiving his doctorate from Kiel in 1881. Up to this time his work had not touched the field of anthropology, which he, more than any other person, was to mark out and develop. His dissertation was on the color of sea water, and he undertook what proved to be the first of his anthropological field trips in the pursuit of his interest in geography and physics. This expedition was to Cumberland Sound and Davis Strait, where he spent the better part of the years 1883 and 1884 among the Central Eskimo. Under the influence of Ratzel he had expected to demonstrate geographical determinism, but his appreciation of the far-reaching significance of the forms of the cultural life of this people finally determined his life work. He returned from Hudson Bay with material on the geography of the region, but he had in addition abundant data on the cultural life of the Central Eskimo as well as an ethnographical collection of specimens.

He returned to Germany, where he was assistant in the Royal Ethnological Museum in Berlin under Bastian, and docent of geography in the University of Berlin. In 1886 he undertook ethnological investigations in still another primitive field for the British Association for the Advancement of Science. It was among the Indians of the North Pacific Coast of North America that he began the anthropological field work with which he has identified himself throughout his life. From this time till 1897 he made repeated trips to this region, investigating the cultural life of the various tribes up and down the

coast, collecting mythological material and ethnographical specimens, taking measurements of bodily form, recording linguistic texts and making grammatical analyses. After 1897 the work was continued as the Jesup Expedition, and was enlarged to include a number of investigators under his direction.

From 1888 to 1892 he was docent of anthropology at Clark University. He was chief assistant of the department of anthropology at the Chicago Exposition in 1893, and to him was largely due the success of that first scientific exhibition of American ethnology. At the close of the World's Fair he took charge of the collections made there as curator of the department of anthropology of the Field-Columbian Museum, coming, in 1896, to the American Museum of Natural History in New York City where he was assistant curator and curator till 1905. From the time of his coming to New York he was lecturer in physical anthropology in Columbia University, and from 1899 until the present time he has been professor of anthropology at that institution. In 1912, he lectured at the International School of Archeology and Ethnology in Mexico City and, in 1924, at the Institute of Culture History at Oslo.

Besides his life-long anthropological work on the North Pacific Coast Dr. Boas has carried on investigations in Porto Rico, in Mexico and in the Southwest pueblos, and is at the time of his election as president of the American Association for the Advancement of Science spending his sabbatical term among the Kwakiutl Indians of Vancouver Island, the tribe of the Northern Coast with which he has been most closely identified.

Alone among anthropologists Dr. Boas has worked in the three major

fields of anthropology: physical anthropology and anthropometry; linguistics; and cultural anthropology. Archeology is the only branch of anthropology to which he has not made major personal contributions. In his work in physical anthropology he has constantly called attention to the necessity of investigations into the rates and processes of physical change so that we may know something of the behavior of physical measurements under various hereditary and environmental conditions, information that is necessary before we can intelligently use physical statistics as a basis for the classification of human groups. In linguistics he has set a high standard for the recording of primitive languages and for the analysis of their grammatical forms, and has interested himself in the processes of linguistic development and in the use of this material in historical reconstruction. In cultural anthropology he has emphasized the importance of a twofold approach, the one aiming at the most complete and fully interrelated study of the different aspects of the cultural life of any peoples, and the other aiming to place this culture and the different aspects of it in its broad setting as one local variant of much wider distributions. The latter of these emphases has led to his interest in historical reconstruction of those parts of the world without written records, and the former to his insistence on the great rôle played by the forms of institutional life in the psychology of any peoples, and his understanding of the possible equal value of very divergent cultural forms.

It is seldom that one man has been so largely responsible for the history of a scientific discipline as Dr. Boas of anthropology. Almost every American anthropologist has been a student of Boas, and his work in all fields of anthropology has made him a leader in fact as well as in name.

The honors that he has received have been in keeping with his achievements. The degree of LL.D. was conferred upon him by Oxford University and Clark University, the degree of Sc.D. by Oxford University and Columbia University and the honorary Ph.D. by the University of Graz. He was made a member of the National Academy of Sciences in 1900. He was president of the American Anthropological Association from 1907 to 1909, of the New York Academy of Sciences in 1910, of the XXIII International Congress of Americanists in 1928.

For years he has held offices which involve incessant labor, not only of organization and administration but even of financing. He was editor and guiding spirit of the Jesup North Pacific Expedition series and of the American Folk-Lore Society. He is editor of the American Ethnological Society, of the Columbia University Contributions to Anthropology, and of the *International Journal of American Linguistics*, to mention only a few.

He submitted plans and secured funds from the Carnegie Institution for a concentrated drive to get written records of the nearly extinct Indian languages of North America. In less than five years some twenty-three grammars have been written under his direction; the work is continuing and may soon be extended to include Latin America.

His bibliography is extensive, but the following may be singled out for special mention: "The Growth of Children," 1896, 1904; "Social Organization and Secret Societies of the Kwakiutl," 1897; "Changes in Bodily Form of Descendants of Immigrants," 1911; "Tsimshian Mythology," 1909; "The Mind of Primitive Man," 1911; "Kultur und Rasse," 1913; "Primitive Art," 1927; "Anthropology and Modern Life," 1928.

R. B.

THE WORK OF DR. BURTON E. LIVINGSTON AS PERMANENT SECRETARY OF THE AMERICAN ASSOCIATION

UPON the resignation of Dr. Burton E. Livingston as permanent secretary of the American Association for the Advancement of Science, it is appropriate that we express our appreciation of the great contribution he has made to American science during the eleven years that he has devoted to the reorganization of the work of the association, following the adoption of the new constitution at the St. Louis meeting in December, 1919.

Many excellent features of the work of the association are now so familiar to us that we are apt to forget that they are recent developments, largely devised and put into effective operation by Dr. Livingston. Among these may be mentioned the Preliminary Announcement and Reports of the Annual Meeting (as they appear in special issues of *Science*), the remarkably interesting general sessions and non-technical lectures that form a conspicuous part of the annual meetings, the Annual Science Exhibition, the Association Press Service, the Association Prize, the Secretaries' Conference, the Academy Conference, the General Program with its convenient system of key symbols, and the method now in use for securing fellowship nominations. Although some of these features originated earlier in the history of the association, their present form and high degree of excellence are due almost entirely to the development that has occurred under the efficient leadership of Dr. Livingston.

The most tangible index of the remarkable development of the American Association under Dr. Livingston's guidance is the extraordinary growth in membership that has occurred during the last decade. The membership has grown steadily at an average rate of nearly eight hundred new members each year. From 11,442 in 1920 it has increased to over 19,000 at the present time. Growth in numbers has been ac-

companied by a less readily evaluated but even greater increase in interest displayed by members in all aspects of the work of the association. The rapidly growing appreciation of the work of the association and all that it means to science and education in America is shared by members of its one hundred and twenty-two associated organizations, representing all of the many thousands of American scientific investigators, teachers, and friends of science.

Dr. Livingston has shown remarkable executive ability in framing the broader policies of the association that look to the future as well as in handling the innumerable details of administration. He brought to his work an unyielding earnestness of purpose in advancing what he conceives as a great cooperative movement, capable of exerting a powerful beneficial influence upon science and civilization. Endowed with sound judgment and rare ability as an executive, Dr. Livingston has devoted sixteen hours a day, during the strenuous period before and after the annual meetings, to his combined duties as permanent secretary of the association and director of the Laboratory of Plant Physiology of the Johns Hopkins University. During the meetings his day rarely was finished until three or four o'clock in the morning—with the council regularly meeting at nine.

The members of the council and of its executive committee, inspired largely by the permanent secretary, have shown a constantly growing interest and enthusiasm in governing the activities of the association. They have cooperated in every possible way with Dr. Livingston and have depended upon his judgment for many important decisions affecting the policies of the association. The permanent secretary has been helped by a small but exceptionally efficient staff of assistants in the Washington office,

fields of anthropology: physical anthropology and anthropometry; linguistics; and cultural anthropology. Archeology is the only branch of anthropology to which he has not made major personal contributions. In his work in physical anthropology he has constantly called attention to the necessity of investigations into the rates and processes of physical change so that we may know something of the behavior of physical measurements under various hereditary and environmental conditions, information that is necessary before we can intelligently use physical statistics as a basis for the classification of human groups. In linguistics he has set a high standard for the recording of primitive languages and for the analysis of their grammatical forms, and has interested himself in the processes of linguistic development and in the use of this material in historical reconstruction. In cultural anthropology he has emphasized the importance of a twofold approach, the one aiming at the most complete and fully interrelated study of the different aspects of the cultural life of any peoples, and the other aiming to place this culture and the different aspects of it in its broad setting as one local variant of much wider distributions. The latter of these emphases has led to his interest in historical reconstruction of those parts of the world without written records, and the former to his insistence on the great rôle played by the forms of institutional life in the psychology of any peoples, and his understanding of the possible equal value of very divergent cultural forms.

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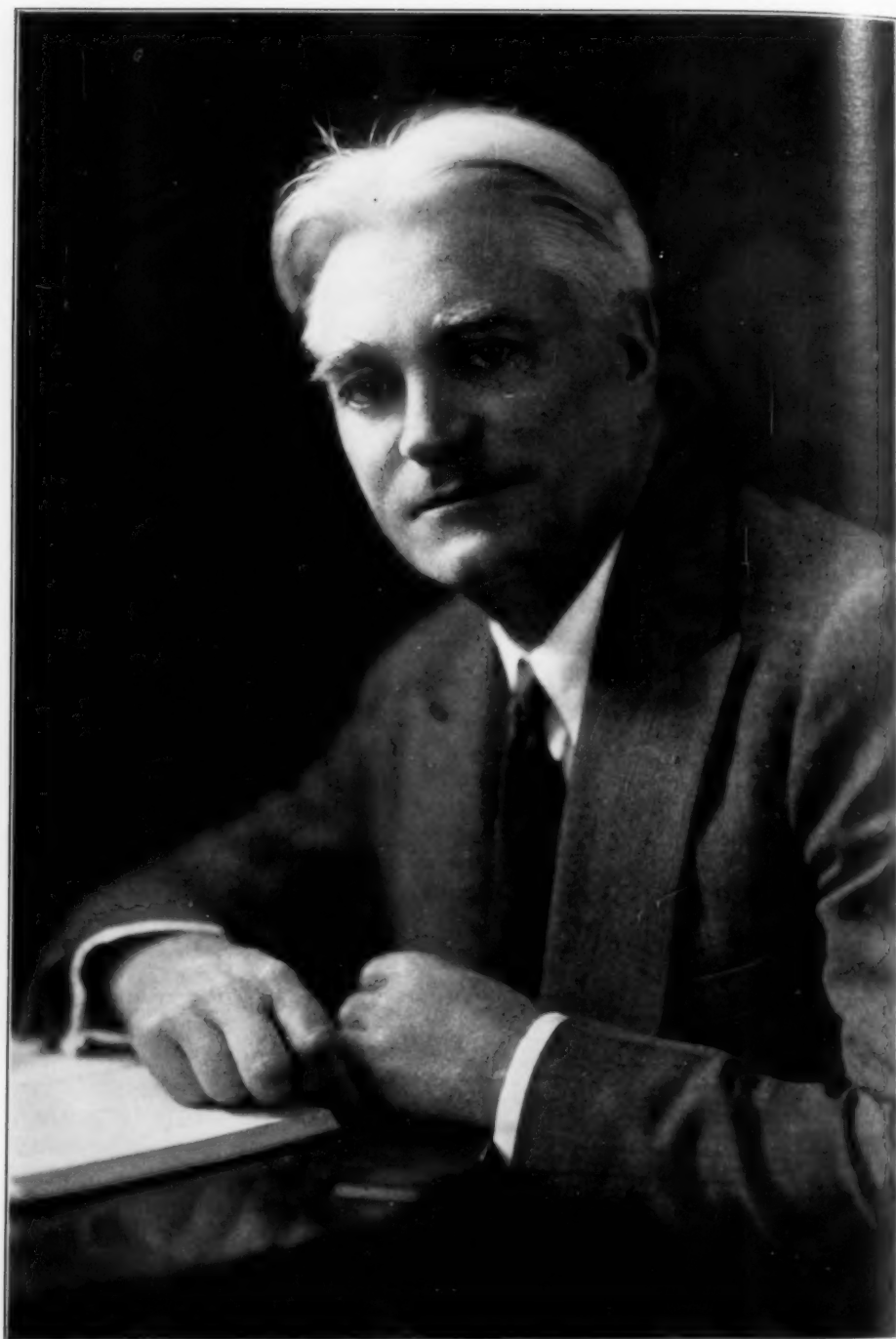
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headed, throughout his term, by Mr. Sam Woodley. And an increasingly helpful cooperation of the section and society secretaries has been an important factor in the growing influence of the association on American science.

One of the most valuable contributions made by Dr. Livingston is in the publication of readable and interesting reports of each annual meeting. These generally have filled one whole issue of *Science*, and they are of great interest to all who have attended the meeting as well as to those who have remained at home. The Preliminary Announcement, likewise published in a special issue of *Science*, is now a publication of great importance to all members of the association. Few people can realize the enormous task involved in the preparation of these publications, all the material for which has been reorganized and much of it rewritten by Dr. Livingston.

The Secretaries' Conference and Dinner, organized by Dr. Livingston, forms an important gathering at which all the society and section secretaries meet with the executive committee of the association and work out plans by which the activities of the various groups are coordinated. Under the guidance of the permanent secretary the relations of the academies of science to the association have developed in a very satisfactory way. An efficient means to this end is the Academy Conference and Dinner, at which representatives of the affiliated academies meet with representatives of the association at each annual meeting.

Great service has been rendered by Dr. Livingston in placing the financial affairs of the association on a secure and satisfactory basis. Marked improvements have been made in the financial arrangements for the annual meetings and in the handling of the general current funds of the association. Additions have been made to the permanent endowment of the association; the methods

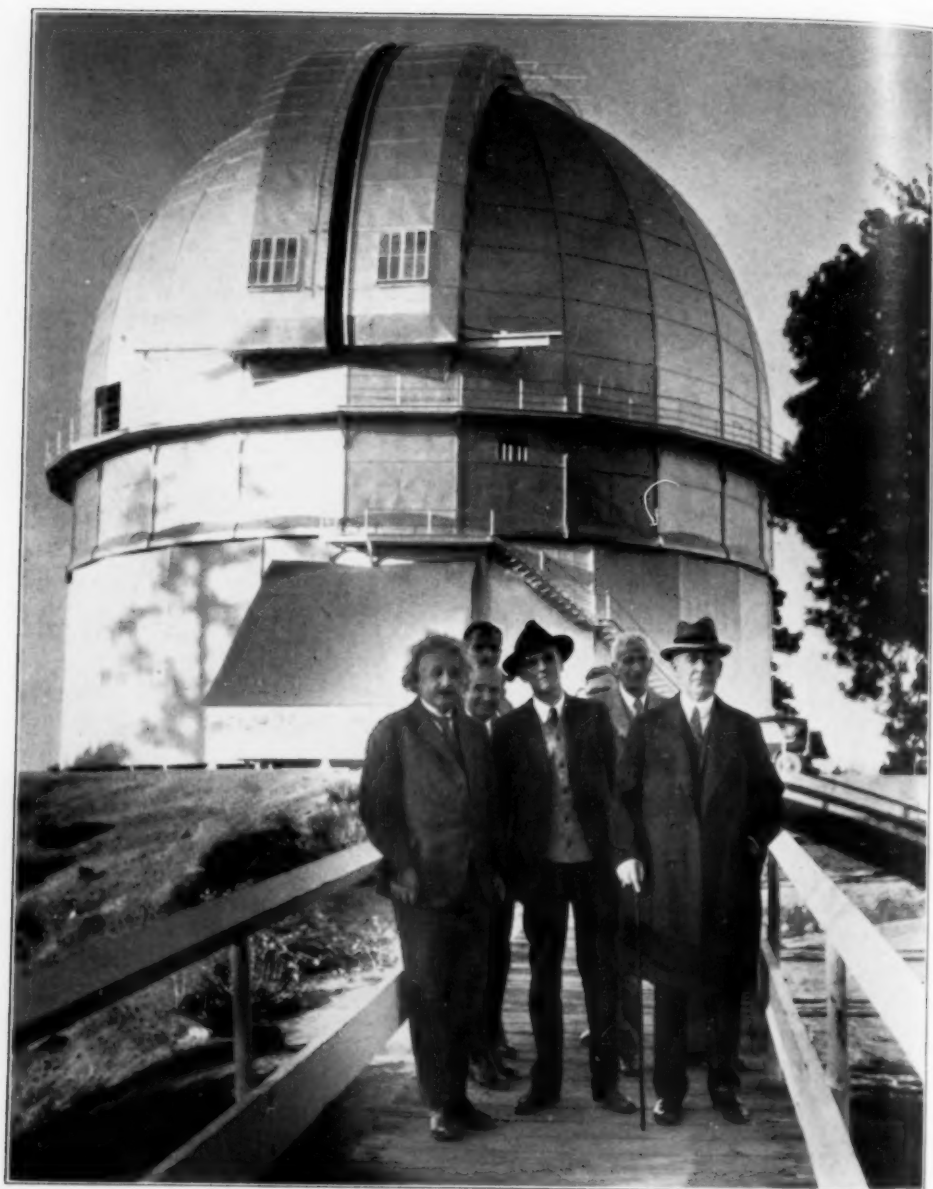
of investment of the permanent funds by the finance committee and the use of income from these funds now offer every possible encouragement for additional donations.

Dr. Livingston retires from his duties as permanent secretary of the American Association to devote his full time and attention to his academic work at the Johns Hopkins University, where he has been professor of plant physiology since 1909 and director of the Laboratory of Plant Physiology since 1913. One of the foremost authorities in the world on the water relations of plants, Dr. Livingston is author of more than one hundred and seventy-five papers on plant physiology, and of several books, including "Rôle of Diffusion and Osmotic Pressure in Plants," "The Relation of Desert Plants to Soil Moisture and to Evaporation," and "Distribution of Vegetation in the United States as Related to Climatic Conditions" (with F. Shreve). He has also translated and edited the English edition of Palladin's "Plant Physiology." A number of instruments devised by Dr. Livingston are used throughout the world in physiological research. These include the porous-cup atmometer (for measuring evaporation as a climatic factor), the auto-irrigator (for automatic control of soil moisture of potted plants), water-absorbing points (for measuring water-supplying power of soils), and rotating tables (for assuring equal exposure of plant cultures to environmental conditions).

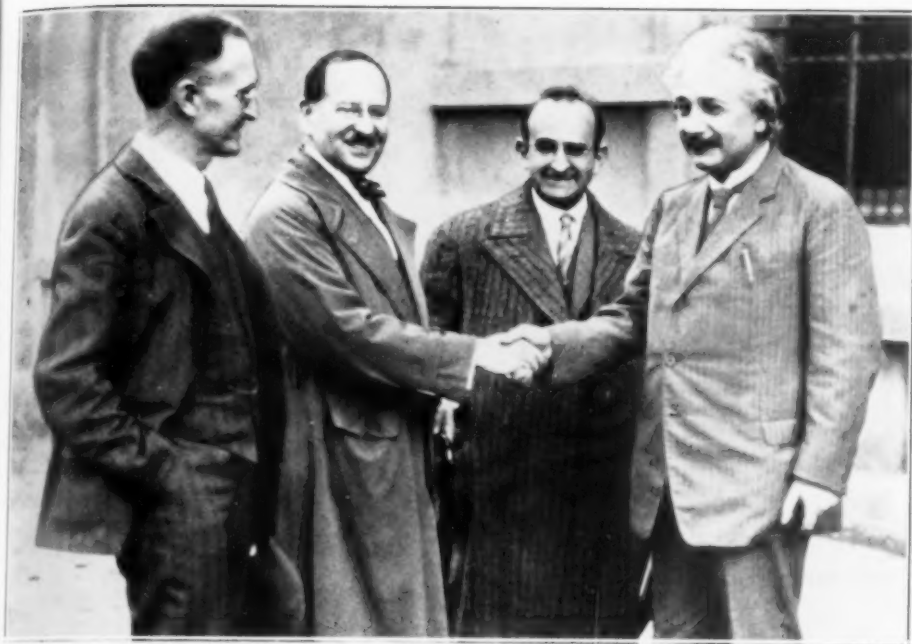
The association feels very grateful to Dr. Livingston for the years that he has devoted, enthusiastically and tirelessly, to its work; it congratulates him on his great achievements as permanent secretary; and it extends to him best wishes for further successes in his own field of scientific research.

SAM F. TRELEASE,

*Secretary, Section G,
Secretary of the Council, 1921-30*



PROFESSOR EINSTEIN AT PASADENA
PROFESSOR F. H. SEARES, PROFESSOR P. S. EPSTEIN, DR. WALTER MAYER
AND PROFESSOR EINSTEIN.



PROFESSOR EINSTEIN AT THE MOUNT WILSON OBSERVATORY

PROFESSOR EINSTEIN, DR. WALTER S. ADAMS, DIRECTOR OF THE OBSERVATORY, AND WILLIAM WALLACE CAMPBELL, DIRECTOR EMERITUS OF THE LICK OBSERVATORY AND PRESIDENT EMERITUS OF THE UNIVERSITY OF CALIFORNIA.

SIR CHANDRASEKHARA VENKATA RAMAN, NOBEL LAUREATE

IN awarding the Nobel Prize in physics for 1930 to Sir C. V. Raman, the Swedish Academy concurred with physicists the world over in appraising the discovery of the "Raman effect" as one of the most important achievements in physics in recent years.

As on some previous occasions, the award this time is made, nominally at any rate, for a single experimental result of striking importance rather than for a high standard of productivity maintained over a period of years. Again as on previous occasions, the particular experiment to receive this signal recognition is a rather simple one—one which might have been made with equipment at hand in almost any physical laboratory in the world at any time during the last forty or fifty years. Indeed, within a year of Raman's announcement of his discovery, the effect was

verified and studied by more than forty investigators in countries other than India.

In its simplest form the experiment consists in irradiating a substance composed of molecules with monochromatic light, and observing the spectrum of the light which the substance scatters. Raman found that the scattered light comprises, in addition to a line of the same wave-length as the incident radiation, a few much fainter lines as well, which additional lines are in a sense satellites of the primary line, moving with it as a group through the spectrum when the wave-length of the primary radiation is altered.

In the first definitive experiment of this kind, Raman photographed the spectra of the radiation scattered by various organic compounds when illuminated by a part of the spectrum of a



SIR CHANDRASEKHARA VENKATA RAMAN

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mercury arc. On long exposure the plates revealed these additional or secondary lines not present in the primary light. It was found possible to classify these secondary lines into groups each associated with a single one of the primary lines; corresponding members of the various groups are displaced in frequency each by the same amount from its primary. The different groups may overlap in the spectrum, making the sorting out difficult but not impossible. A group may extend on both sides of the primary; as a rule more and stronger lines are found on the side of lower frequencies. Such lines as do appear on the high frequency side are found always to be matched by lines of equal displacement on the low frequency side. It is as if the scattering material has at its disposal a small collection of frequencies which it can add to that of the incident light or subtract from it, and as if it prefers subtraction to addition. These simple numerical relationships distinguish the Raman effect from the somewhat similar phenomenon of fluorescence—these and the fact that the Raman effect appears to be a universal phenomenon observable with any transparent medium gaseous, liquid or solid, whereas fluorescence is exhibited by a limited class of materials only.

The simple numerical relationships which have been mentioned as characteristic of the Raman effect, and one other which is to be described further on, are easily explained in terms of light quanta and the known properties of molecules. This is one of the reasons for regarding the discovery of the Raman effect as an event of great importance; it makes an addition to the list of phenomena which are conveniently interpreted by regarding light as a corpuscular as well as a wave phenomenon.

Since Einstein in 1906 rehabilitated the corpuscular theory of light to explain the photoelectric effect, and more especially since the discovery of the

Compton effect in 1924, it has become steadily more imperative to recognize that light has these two apparently irreconcilable aspects; a beam of light is a flight of particles or a propagation of trains of waves, depending upon the particular phenomenon which is to be explained or visualized. In explaining some phenomena it is even necessary, or at least convenient, to oscillate between the two views at different stages of the argument. In such cases we make the translation by means of two well established laws: the energy of the light particles or photons is strictly proportional to the frequency (waves per second) of the associated undulations, and similarly the momentum of the photons is strictly proportional to the wave number (waves per centimeter) of the undulations. The factor of proportionality is in both cases the so-called Planck constant h .

In the corpuscular picture the Raman effect is due to interchanges of energy occurring in encounters between the photons of the incident light and the molecules of the scattering material. Photons emerge from these encounters with altered energy; they constitute the scattered light of altered frequency and altered wave-length which Raman detected. Now every kind of molecule or atom has the following peculiar property: its internal energy is limited to certain definite discrete values. The molecule is capable of existence only at certain "energy levels," and can accept or give up energy only in amounts which will raise or lower it, from the particular level in which it happens to be, to another of its levels.

Thus the photons may give up to the molecules only one or another of these characteristic amounts of energy, and, in consequence of the direct proportionality between energy and frequency, the frequency of the associated waves should be lowered only by corresponding amounts. It is for this reason that

the Raman spectrum is a spectrum of sharp lines. The frequency displacements in the Raman spectrum should correspond to differences between energy levels of the molecules; and in cases in which these latter are already known this relationship is verified.

The Raman lines on the high frequency side of the primary line may be explained on the general principle that processes of the kind mentioned in the last paragraph are necessarily reversible. If it is possible for a photon to give up a part of its energy in raising a molecule from one level to another, it must be possible also for the molecule in passing in the opposite direction to impart an equal amount of energy to a colliding photon. This process is the analogue of what is known in encounters between electrons and atoms as a "collision of the second kind." The presence of high frequency components in the Raman spectrum symmetrical with the low frequency components is due to such encounters. These components are weaker than their companions because at ordinary temperatures nearly all of the molecules are in their state of lowest energy and are incapable therefore of imparting energy.

Thus, the importance of Raman's discovery is due partly to its revealing a previously unknown process in nature, partly to the additional basis of reality which it affords to the photon, and partly to its supplying a new and convenient method of investigating the energy levels of molecules.

It was remarked earlier on that the Raman experiment is a rather simple one which might have been made with equipment available in any physical laboratory at any time in recent decades. It was no accident, however, that this particular discovery was made by Raman rather than by someone else. Important discoveries in physics, even quite simple ones, are usually made only by investigators who have cultivated

intensively the particular field concerned, and this is strikingly true in the present instance. No one else in recent years has been as assiduous in the study of the scattering of light as Professor Raman. True, in the years just following his graduation from Presidency College, Madras, in 1907, his interest—if we may judge from his publications—centered chiefly in the vibrations of mechanical systems—stringed musical instruments in particular—and other acoustical problems. But even in these years problems in optics claimed a part of his attention. About 1920, however—three years after he became Sir Taraknath Palit, professor of physics at Calcutta University—he turned abruptly from studies in acoustics and devoted himself almost exclusively to optics and particularly to investigations of scattering, both theoretical and experimental. Of one hundred papers and notes published by Raman independently or in collaboration with his associates and students since that time, eighty-three deal with problems in optics and forty-nine with the scattering of light.

It speaks well for the development of science in India that Professor Raman apparently owes little or nothing of his eminence to direct contact with physicists in other countries. His formal training was received entirely in India, and, except for a single year, he has worked only in his native land. In 1924 he attended the Toronto meeting of the British Association and afterwards carried on his researches for some months at California Institute of Technology.

His previous honors, which have been numerous, include the general presidency of the Indian Science Congress and fellowship in the Royal Society. Knighthood was conferred upon him by King George in 1929. India may well be proud of Sir Chandrasekhara Venkata Raman, her first Nobel Laureate in science.

C. J. DAVISSON